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Forecasting Research

Forecasting Research Division
Technical Report No. 188

Parallel trial of outstanding 3CV physics, correction of boundary layer scheme and revision of orography ancillary files.

by

O M Hammon and S J Lorrimer

March 1996

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PARALLEL TRIAL OF OUTSTANDING 3CV PHYSICS, CORRECTION OF BOUNDARY LAYER SCHEME AND REVISION OF OROGRAPHY ANCILLARY FILES.

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1. INTRODUCTION

In this technical report we present the subjective and objective assessments of the final four components of 3CV (now known as HADAM2b) physics, a correction to a coding error in the boundary layer and changes to the orographic roughness ancillary files. The parallel trial began on 18th October 1995, verification being available from 24th October 1995. The new ancillary files were introduced on 8th November, and the trial ended on 27th November 1995. Thus, we have divided the trial into two halves, with and without the new ancillary field. We will refer to the two halves as phase 1 and phase 2.

There are four components of the 3CV physics package outstanding. These are:

- Improvements to the formulation of mixed cloud (FOCWWIL);
- Correction to the saturation vapour pressure (QSAT);
- MRF/UMIST parametrization for the effective radius of water drops (RE);
- Modifications to large scale precipitation and improvements to the evaporation of precipitation (large scale and convective) (LPPN).

These changes are described in more detail in Milton & Lorrimer (1995), which also describes a series of off line tests of the changes. Milton & Lorrimer find that the overall impact of 3CV is small or neutral. They also find that there are some small improvements:

- Reductions in cloud at the tropopause and in the SH stormtrack;
- Improved planetary albedo;
- Improved SW cloud forcing;
- Warming at the tropopause and in the SH stormtrack.

There are also some, generally less significant, degradations:

- Increased warming/diabatic heating in tropical mid troposphere;
- Increased Hadley circulation;
- Increased tropical circulation;
- Increased cloud in level 1 at high latitudes.

Milton & Lorrimer also assess the impact of correcting the boundary layer coding error, while also doubling the asymptotic mixing length for momentum. They conclude that the combination of these two changes leads to a neutral impact.

The changes in the orographic roughness ancillary files are described in detail in Evans (1996). They include small scale features, such as the highlands of Norway and Scotland, which were not present in the old data set. Locally, the new fields have increased the roughness by 100%. Evans made no changes to the roughness in the Southern Hemisphere. Evans also assessed the impact of the changes in a similar series of off line tests to Milton & Lorrimer. Her overall assessment was that the changes were neutral. However, positive changes were:

- Reduced positive PMSL bias in the Northern Hemisphere;
- Improved 10m wind speed bias in the Northern Hemisphere.

Detrimental changes were:

- Worsening of 500hPa height bias;
- Decreased zonal winds north of 70N.

Near the regions of the greatest changes in the roughness, *ie,* Norway and North West Britain, there are changes to the 10m wind and PMSL patterns. However, Evans did not feel it was possible to assess if these were beneficial or not.

The purpose of this trial was to test if the impact seen in these studies, which were run off line from operational analyses, were reproduced in a quasi-operational environment that includes a continuous assimilation cycle.

2. Objective Verification

The objective verification was carried out using the new verification scheme (Radford 1992). This allows verification against analyses, upper air soundings, air reps or AMDARs. Verification is available from 24th October 1995. In this report we only show selected verification scores.

2.1 Global Verification

The verification has been divided into four areas: area 2, Northern hemisphere to 30N, Tropics between 30N and 30S and Southern Hemisphere from 30S. For each field the bias and RMS have been found. For verification against analyses the anomaly correlation was also found. However, even by T+120 this had shown very little impact and so we will not discuss it here, except to note that it reflects the neutral overall impact of the package.

Inevitably, verification was not available for the entire period due to difficulties with both the parallel suite and the new verification scheme. In Table 2.1 we show those dates for which

we could obtain verification. Note that these are different from those given in the table in the note 'Parallel suite experiment 036 (EXP036) summary' (Bean 1995), which gives those which ran successfully. These may not have been successfully verified.

TABLE 2.1

Forecast ranges that are available for verification of global model fields as a function of verifying date during October and November 1995.

	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9
T+24	✔	✔	✘	✔	✔	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔	✔	✘
T+48		✔	✘	✔	✔	✘	✘	✘	✔	✘	✔	✘	✔	✔	✔	✔	✔
T+72			✘	✔	✔	✔	✘	✘	✔	✔	✘	✔	✘	✔	✔	✔	✔
T+96				✔	✔	✔	✘	✘	✘	✔	✔	✘	✘	✘	✔	✔	✔
T+120					✔	✔	✔	✘	✘	✘	✔	✔	✘	✘	✘	✔	✔

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
T+24	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔
T+48	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔
T+72	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔
T+96	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔	✔	✘	✔
T+120	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔	✘	✔

In the following discussion we will refer exclusively to phase 2. The results of phase 1 are consistent with those discussed.

2.1.1 Verification Against Upper Air Soundings

Before the implementation of the new verification scheme, verification against upper air soundings was the only observational verification available for upper levels. Consequently, when comparing this trial against previous ones, this section, and the section on verification against surface observations, represents what would previously have been described as 'verification against observations'.

The model geopotential height (see **Figure 2.1**) has increased; the change grows from 0.5m at T+24 to 3m at T+120 (at all levels). This has lead to an improvement in the bias at all times and in all areas, except area 2. In area 2 the bias, shown in **Figure 2.2**, is already positive below 400hPa for forecast times out to T+72. Consequently, the increase in height is detrimental. The RMS scores are largely unchanged, except in the tropics, where there is a 2-3% improvement.

Temperatures, shown in **Figure 2.3**, are warmer by 0.1-0.2K below 500hPa in area 2 and the NH; this is generally useful is reducing the cold bias. In the tropics and SH (also **Figure 2.3**) there is no significant change until after T+72 and below 850hPa, where the warming is less than 0.1K. The RMS errors show a 2-4% improvement, especially in the lower levels and at early times.

The relative humidities are drier, leading to an absolute reduction in the moist bias of 1-2% at 850hPa (see, for example, **Figure 2.4** showing the results for the tropics at T+120). This may due to the improvements in temperature discussed above, but QSAT is also likely to have had an impact. There is also a large relative improvement in the RMS scores in the SH of around 2%. This is greatest near the surface.

The wind speed bias suggests that the wind strength has increased by 0.05-0.1ms^{-1}, leading to a reduction in the negative bias. This is shown in **Figure 2.5** for the NH, tropics and SH at T+120. The RMS VWE shows less impact, the only significant change being a reduction in the SH of about 2% at 200hPa.

2.1.2 Verification Against Air Reps

The NH temperatures show a beneficial warming of around 0.05 K at 200hPa at T+24 (**Figure 2.6**). This improvement propagates downwards and increases as the forecast progresses. By T+120 the warming in the NH at 300hPa has reached 0.1K (also shown in **Figure 2.6**). There is a useful warming at all levels and in all areas by T+96. This is also apparent in the RMS, which shows an improvement of up to 3% by T+120 in area 2 and the SH. The relative improvement in the trial RMS is shown in **Figure 2.7**.

In both the tropics and the SH there is a useful strengthening of the winds (**Figure 2.8**). For instance, by T+24 the trial tropical winds are stronger by 0.1ms^{-1}. The effect is weaker in the NH and area 2.

2.1.3 Verification Against AMDARs

A problem in the verification scheme has prevented us from verifying AMDAR winds. However, the AMDAR temperatures are still useful. These show a warming at low levels of up to 0.1K, which is typically beneficial. By T+120 the RMS error in the SH has improved by up to 6%, although the change in the NH is generally neutral (**FIGURE 2.9**).

2.1.4 VERIFICATION AGAINST SURFACE OBSERVATIONS

The PMSL shows a reduction in the bias at all times and in all areas (**FIGURE 2.10**). There is a slight reduction in the area 2 RMS error (1-5%) late in the forecast (**FIGURE 2.11**).

The 10m wind speed bias has also reduced or become more negative, which is beneficial in the tropics (an improvement of about $0.02ms^{-1}$ at T+120). However, elsewhere this is detrimental (see **FIGURE 2.12**).

The verification of 1.5m temperature is the most worrying aspect of the objective verification. Typically, the temperatures are 0.5K cooler in the extra-tropics and 0.1K cooler in the tropics. This is a significant deterioration in the bias (**FIGURE 2.13**). The RMS error has also deteriorated by up to 6%.

2.1.5 VERIFICATION AGAINST ANALYSES

Usually the operational and parallel suite forecasts are verified against their own analyses. However, during this trial both global forecasts are verified against the *operational update analyses*. In the LAM, the forecasts continue to be verified against their own analyses.

The improvement in PMSL that we noted in section 2.4 is also apparent in the tropics here, where there is an increase of about 5Pa by T+120. In other areas there is also an improvement of up to 5Pa (**FIGURE 2.14**). The RMS error also reduces in area 2 and the SH by about 2%.

The geopotential height is increased at all levels and times by $\sim$1m. This is generally beneficial, except below 500hPa in the NH and area 2, where there is already a positive bias (**FIGURE 2.15**). The RMS scores show improvements of up to 6%, especially at upper levels.

As we noted above, below 500hPa the parallel suite is warmer by about 0.1K, and this shows up in the verification against analyses by generally reducing the cold bias (**FIGURE 2.16**). The RMS shows deteriorations at early forecast times (T+24) of up to 6%. However, by T+120 the impact is generally neutral or a slight improvement (see, *eg*, 850hPa level, **FIGURE 2.17**).

As when verifying against upper air soundings, the relative humidity is generally drier. However, when verifying against analyses, it is less clear that this is a beneficial change, especially early in the forecast. Indeed the RMS error for the tropical RH shows a startling 25% deterioration at 950hPa at T+24, reducing to a deterioration of 2% by T+120 (**FIGURE 2.18**). However, this field is particularly noisy and the error against analyses is significantly smaller than that against upper air soundings.

The wind speed bias again suggests that the winds have strengthened by 0.05-0.1ms^{-1}. This is largely beneficial in area 2 and the NH, but not in the tropics and SH. For instance, **FIGURE 2.19** shows the SH and NH scores at T+120.

The 10m winds have weakened by at most 0.05ms^{-1}, which is generally beneficial. The exception to this is area 2, where the change is slightly detrimental (**FIGURE 2.20**). There is no significant change in the RMS scores.

Again the 1.5m temperatures show a significant degradation. The cold bias deteriorates by 0.1-0.2K and the RMS is 10% worse at T+24, although this degradation reduces with increasing forecast range. This is shown for the NH and tropics in **FIGURE 2.21**.

2.1.6 SUMMARY AND DISCUSSION OF GLOBAL VERIFICATION

In previous parallel suite reports tables have been presented giving the number of RMS scores which have changed in the trial by more than 1%. The figure of 1% is somewhat arbitrary, but is chosen to reflect the level of practical significance. The scores are not weighted in any way. So, if a score is calculated on more pressure levels it will receive more weighting. Also, less important fields, such as relative humidity are given an equal weighting to more important fields such as wind. Using the new verification scheme has lead to a wider range of scores being calculated and so the counts of scores presented here are not comparable with parallel suites using the old scheme. In addition, we have broken the total down by observation type as well as verification area. These are given in Tables 2.2-2.5. This crude analysis suggests that the impact of the trial is neural.

TABLE 2.2

The number of RMS scores which have improved or deteriorated in phase 2 of the parallel suite when verifying against upper air reports. A change of more than 1% is considered to be significant.

	Better	Neutral	Worse	Total
Area 2	19	130	1	150
NH	5	142	3	150
Tropics	47	92	11	150
SH	35	103	12	150
Total	106	467	27	600

TABLE 2.3

The number of RMS scores which have improved or deteriorated in phase 2 of the parallel suite when verifying against air rep's. A change of more than 1% is considered to be significant.

	Better	Neutral	Worse	Total
Area 2	8	22	0	30
NH	4	26	0	30
Tropics	0	21	9	30
SH	5	22	3	30
Total	17	91	12	120

TABLE 2.4

The number of RMS scores which have improved or deteriorated in phase 2 of the parallel suite when verifying against surface observations. A change of more than 1% is considered to be significant.

	Better	Neutral	Worse	Total
Area 2	6	6	6	18
NH	3	9	6	18
Tropics	3	10	5	18
SH	1	12	5	18
Total	13	37	22	72

TABLE 2.5

The number of RMS scores which have improved or deteriorated in the parallel suite when verifying against analyses. A change of more than 1% is considered to be significant.

	Better	Neutral	Worse	Total
Area 2	35	121	30	186
NH	15	135	36	186
Tropics	43	72	71	186
SH	11	138	37	186
Total	104	466	174	744

TABLE 2.6

The number of RMS scores which have improved or deteriorated in phase 1 of the parallel suite when verifying against all sources. A change of more than 1% is considered to be significant.

	Better	Neutral	Worse	Total
Area 2	115	242	27	384
NH	52	297	35	384
Tropics	106	191	87	384
SH	109	223	52	384
Total	382	953	201	1536

As we mentioned above, the verification scores in phase 1 and phase 2 are consistent. To demonstrate this Table 2.6 shows the total number of scores which changed by more than 1% during phase 1, which should be compared with Table 2.7. During phase 1 the signal is more positive. However, some of the biggest differences are in the southern hemisphere, where Evans made no change to the roughness. We therefore conclude that the two halves of the test are not significantly different. This is also suggests that the 1% threshold may not be the most appropriate method for assessing the overall impact of changes on the verification scores.

TABLE 2.7

The number of RMS scores which have improved or deteriorated in phase 2 of the parallel suite when verifying against all sources. This is the sum of Tables 2.2-2.5 and should be compared with Table 2.6, which is for phase 1. A change of more than 1% is considered to be significant.

	Better	Neutral	Worse	Total
Area 2	68	279	37	384
NH	27	312	45	384
Tropics	93	195	96	384
SH	52	275	57	384
Total	240	1061	235	1536

An alternative method of summarising the overall impact of the change is now available to us via the NWP index. The index has the advantage, over the enumeration of significantly changed scores, that the scores are given a weighting, which reflects the importance of an accurate forecast of a particular field. The index, I_j, for month j is defined as

$$I_j = \frac{100}{\sum W_i} \sum W_i \frac{E_i}{\varepsilon_{ij}}$$

where W_i is the weighting for the i^{th} score, E_i is the value of that score during the reference year (1991) and ε_{ij} is the value meaned over month j. For monitoring the long term performance of the model a twelve month rolling mean of I_j is formed. Although the parallel suite runs for less than a month (and in general across the ends of months) it is useful to assess the possible impact of a change by calculating $\overline{I}$. This has an identical definition to I_j except that ε_{ij} is replaced by $\overline{\varepsilon_i}$, which is the mean of the i^{th} score over the period of the parallel trial. $\overline{I}$ then gives an estimate of the expected impact on the rolling mean I_j twelve months after the change is implemented operationally. Since the E_i are annual means, the effective weight of the summer hemisphere, when the scores tend to be lower, is increased.

Table 2.8 lists the various W_i, E_i and $\overline{\varepsilon_i}$ for both the parallel trial and the operational forecast during phase 2. Also shown is the contribution to $\overline{I}$ and the change in this. A positive change in $\overline{I}$ is beneficial.

TABLE 2.8

The impact of the package tested in the parallel suite on the NWP index.

Area	Field	VT	W_i	E_i	$\overline{\varepsilon_i}$ control	$W_i E_i / \overline{\varepsilon_i}$ control	$\overline{\varepsilon_i}$ test	$W_i E_i / \overline{\varepsilon_i}$ test	$\Delta \overline{I}$
NH	PMSL	T+24	10	220.0	194.8	11.29	193.4	11.38	0.08
NH	PMSL	T+48	8	350.0	331.2	8.45	328.1	8.53	0.08
NH	PMSL	T+72	6	470.0	495.5	5.69	491.2	5.74	0.05
NH	PMSL	T+96	4	570.0	679.9	3.35	673.3	3.39	0.03
NH	PMSL	T+120	4	680.0	843.1	3.23	846.4	3.21	-0.01
NH	H500	T+24	6	15.9	15.6	6.12	15.4	6.18	0.06
NH	H500	T+48	4	28.8	29.9	3.86	29.8	3.87	0.01
NH	H500	T+72	2	42.8	47.8	1.79	47.8	1.79	0.00
NH	W250	T+24	12	6.0	5.9	12.24	5.8	12.31	0.06
Tropics	W850	T+24	5	3.3	2.3	7.05	2.4	6.90	-0.15
Tropics	W850	T+48	3	4.3	3.2	3.98	3.3	3.96	-0.02
Tropics	W850	T+72	2	5.0	4.0	2.51	4.0	2.51	-0.01
Tropics	W250	T+24	6	5.2	4.5	6.92	4.6	6.74	-0.18
SH	PMSL	T+24	5	290.0	231.2	6.27	231.3	6.27	0.00
SH	PMSL	T+48	4	470.0	377.8	4.98	377.3	4.98	0.01
SH	PMSL	T+72	3	620.0	522.6	3.56	520.6	3.57	0.01
SH	PMSL	T+96	2	760.0	655.9	2.32	655.7	2.32	0.00
SH	PMSL	T+120	2	870.0	811.2	2.14	814.8	2.14	-0.01
SH	H500	T+24	3	24.1	20.4	3.54	20.3	3.56	0.03
SH	H500	T+48	2	42.4	36.7	2.31	36.4	2.33	0.02
SH	H500	T+72	1	59.5	52.3	1.14	52.1	1.14	0.00
SH	W250	T+24	6	6.3	5.6	6.79	5.6	6.81	0.02

The nett impact of the individual contributions to the NWP index itemised in Table 2.8 is that the control index is 109.54 and the test index is 109.63; this is an overall improvement of 0.09, although it is probably not statistically significant. Most of the positive contribution

comes from the northern hemisphere forecasts of PMSL and 250hPa wind. These fields are all relatively underweighted in the index as for the period of the parallel trial $\overline{\varepsilon_i} > \varepsilon_{ij}$ meaned over 12 months and so we might hope that this null result represents a lower limit on the impact of this package on the NWP index.

The overall signal is that the scores have generally improved by a small amount, although not dramatically. The improvements are clearer in the verification against observations than in the verification against analyses. However, the two are not inconsistent. The geopotential height, temperature, RH, wind and PMSL all show an overall improvement. The only field to have been degraded is the 1.5m temperature, which is known to be very sensitive.

The results are also consistent with Milton & Lorrimer (1995). An exact comparison is not possible as their tests were for JF and JJA, but in general the signals are of a similar magnitude. They found that the temperature bias was reduced by about 10%. Whilst we found a reduction which is closer to 20% at its maximum, the results are in reasonable agreement, especially at middle and lower levels. However, at 250hPa Milton & Lorrimer found a significant positive impact. This may only be apparent during mid-season.

2.2 LAM Verification

The LAM results were verified over a similar period to the global model using forecasts verifying at T+12, T+24 and T+36. The forecasts were verified against upper air reports, surface observations and analyses. Note that in this case verification against analysis was against the operational and parallel suite analyses as appropriate. We have calculated the verification scores for two areas, the full LAM area (aka area 888) and 'area 5' covering the UK and Iceland.

In Table 2.7 we show those dates on which the three forecast ranges considered could be verified. Note that, as for the global model tests, these do not tally with the table given in Bean (1995).

TABLE 2.9

Forecast ranges which are available for verification of LAM fields as a function of verifying date during October and November 1995.

	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9
T+12	✘	✔	✔	✔	✔	✔	✔	✔	✔	✘	✘	✔	✔	✔	✔	✔	✘
T+24	✘	✘	✘	✔	✔	✔	✔	✔	✔	✔	✘	✘	✔	✔	✔	✔	✔
T+36	✘	✘	✔	✔	✔	✔	✔	✔	✔	✘	✘	✘	✔	✔	✔	✔	✔

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
T+12	✔	✘	✘	✘	✔	✘	✘	✔	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔
T+24	✔	✘	✘	✘	✘	✔	✘	✘	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔
T+36	✔	✘	✘	✘	✘	✘	✘	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔	✔

In the following discussion we shall refer, unless indicated otherwise, exclusively to phase 1. The results of phase 2 are consistent with these.

2.2.1 UPPER AIR VERIFICATION

The geopotential height in the trial is increased at all levels by 0.5m at T+12, rising to increases of up 3m by T+36 (**FIGURE 2.22**). Over the UK and Iceland, the RMS height errors deteriorate by 1-2% at T+12, but by T+24 and T+36 RMS height errors have decreased by up to 4% (**FIGURE 2.23**).

The temperature errors showing a significant warming in the trial below 500hPa. For instance, the trial is generally 0.5K warmer at 850hPa than the operational run. This change is generally positive, but, as shown in **FIGURE 2.24**, is a little overdone when the whole LAM is considered. The changes in the RMS temperature errors are noisy, but they suggest that over the UK and Iceland RMS errors have been reduced by up to 3% at T+36 (**FIGURE 2.25**).

The relative humidities are dryer by 1% (in an absolute sense) at 850hPa and T+12. This rises to 1.5% by T+36 and propagates upwards (**FIGURE 2.26**). The RMS errors are again quite noisy, but they suggest that over the UK and Iceland upper level RMS errors are reduced by up to 2%.

At T+12, below 300hPa, the wind speed bias is more negative by up to 0.1ms^{-1}. Conversely, at T+24 and T+36 the bias is less negative (*ie,* improved) by an amount of the same magnitude. Also at T+36 the 850hPa RMS VWE deteriorates by about 0.5ms^{-1} (**FIGURE 2.27**).

2.2.2 SURFACE VERIFICATION

The verification of surface 'observed' PMSL shows that in the trial pressure is reduced by up to 20Pa (**FIGURE 2.28**). This acts to improve the existing bias. The RMS error shows no significant change except at T+24 over UK and Iceland, where it improves by 4%.

Verification of 1.5m temperature is only available for UK and Iceland. Here, there is a warming of around 0.4K and the RMS error deteriorates by between 4% and 12% (**FIGURE 2.29**).

The 10m wind speed bias has increased by up to 0.15ms^{-1} (**FIGURE 2.30**). This is a detrimental change. There is no significant impact on the RMS error.

2.2.3 VERIFICATION AGAINST ANALYSES

The trial PMSL is lower by up to 20Pa. This is detrimental at T+36, and probably also at T+24 (**FIGURE 2.31**). This is also apparent in the RMS errors (**FIGURE 2.32**) which show deteriorations of up to 7%.

The trial geopotential heights are increased by around 2m, which reduces the bias at T+24 and T+36 (**FIGURE 2.33**). However, at T+12, below 400hPa the same reduction in geopotential height worsens the bias. These changes are also reflected in the RMS scores, where the changes vary between +10% and -10% (**FIGURE 2.34**).

The trial temperatures are warmer below 500hPa by up to 0.5K (at 850hPa, **FIGURE 2.35**). This is largely beneficial, except near the surface where the warming is little excessive and the cold bias becomes a warm bias. Contrary to the global results, the 1.5m temperatures are warmer (**FIGURE 2.36**). This is detrimental as there is already a warm bias.

In the trial, RHs are drier by up to 2% (absolute change), especially at lower levels (**FIGURE 2.37**). The drying is excessive for the full LAM area at 850hPa, but the error here is small in any case.

The winds (**FIGURE 2.38**) are 0.2ms^{-1} weaker in the trial at T+12, but up to 0.1ms^{-1} stronger later. This strengthening is beneficial above 800hPa, but detrimental nearer the surface. Similarly, the 10m winds are up to 0.1ms^{-1} stronger at all times (**FIGURE 2.39**) and this is detrimental.

2.2.4 PRECIPITATION VERIFICATION

The precipitation was verified against station observations and the results assessed using contingency tables. The stations are all in the British Isles and a full list is given in Appendix

A2. For these purposes, the rainfall accumulation over six hours was divided into four categories: nil or trace (<0.1mm); light (0.1-2.0mm); moderate (2.0-10.0mm) and; heavy (>10.0mm). The verification was over six hour periods, ranging from T+6-T+12 to T+30-T+36. As an example we show here the trial contingency table (Table 2.8) and operational contingency table (Table 2.9) for T+30 to T+36. The total number of observations is slightly different in each case (800 for the trial and 953 for the operational) so in the tables we have normalised this to 1 for ease of comparison.

To compare the precipitation forecasts, we have calculated a number of statistics: the false alarm rate (FAR); the probability of detection (POD); the frequency bias (FB); the threat score (TS); and the equitable threat score (ETS). The definitions of these statistics and their values are given in Appendix A3. For heavy precipitation there are so few events during the period of the trial we do not believe the scores are trustworthy. All of the changes are small are so we are skeptical about their significance. However, there is a suggestion that the FAR for nil/trace rainfall has increased in the trial for the periods T+12 to T+30, *ie*, the number of stations where the trial incorrectly forecast rain is greater than in the operational control. The only change in the POD seems to be a slight increase for moderate rainfall. The frequency bias is better for light rain, but worse for moderate rain. The TS and ETS show no clear change. Overall, the rainfall verification gives no clear signal of advantage to trial or control.

TABLE 2.10

Contingency table for precipitation accumulation between T+30 and T+36 in the trial. For definitions of the rainfall categories see the test.

	Observed nil or trace	Observed light	Observed moderate	Observed heavy	Total
Forecast nil or trace	0.248	0.075	0.010	0	0.333
Forecast light	0.234	0.189	0.056	0.005	0.484
Forecast moderate	0.048	0.078	0.046	0.006	0.178
Forecast heavy	0.003	0.001	0.003	0	0.006
Total	0.531	0.343	0.115	0.011	1.000

TABLE 2.11

Contingency table for the operational precipitation accumulation between T+30 and T+36. For definitions of the rainfall categories see the test.

	Observed nil or trace	Observed light	Observed moderate	Observed heavy	Total
Forecast nil or trace	0.243	0.083	0.008	0	0.333
Forecast light	0.259	0.180	0.057	0.005	0.502
Forecast moderate	0.052	0.064	0.041	0.004	0.162
Forecast heavy	0	0.001	0.001	0	0.002
Total	0.555	0.328	0.107	0.009	1.000

2.2.5 Station Verification

The introduction of the new orographic roughness ancillary fields during phase 2 had very limited impact in the area averaged objective verification. This is consistent with the results of Evans (1996). The changes are extremely localised and so we felt we might see something if we examined the 10m wind verification for particular stations. We chose four: Wick, Aberdeen, Shawbury and Guernsey Airport. The first three of these are all to the west of areas where significant changes have been made to the roughness fields. Guernsey Airport is included as a control which is well clear of any regions where changes have been made.

The only field in which there was any discernible impact was in the 10m wind speed bias (**Figure 2.40**). For this field the bias has improved for Wick, Aberdeen and Shawbury. However, it has deteriorated for Guernsey. This is tentative evidence that the new roughness field have lead to some improvement of the low level winds. However, the changes are so small and localised that a longer (and cleaner) test is probably required to provide firm evidence of any impact.

2.2.6 Discussion of objective verification of LAM trial

The LAM verification tells a very similar story to the global verification. The heights and temperatures are both improved, but the change is perhaps less clear than in the global model trial. Relative humidities are drier, which is generally beneficial, but the signal is noisy. The wind error varies between being positive and negative.

The surface parameters are a little different, in that the 1.5m temperatures are warmer. However, there is already a warm bias in the LAM and so this change is again detrimental. Ten metre winds have also deteriorated in the trial.

For phase 2 in the LAM we have obtained precipitation verification. Assessing the impact of the change in hit rates and threat scores and contingency is very difficult, but we do not believe there is any significant change. We have also looked at the 10m wind verification for individual stations during phase 2. This suggests that there may be an improvement in the 10m winds, but, again, assessing the significance of this change is very difficult.

3. Subjective Assessment of the Global Model Trial.

The subjective assessment presented in this report will concentrate mainly on Phase 2 of the trial, since this period contained the full package of changes to be considered for operational implementation.

3.1 Impact on forecast evolution

Comparing trial and operational forecasts subjectively, it was apparent that running with the 3CV physics had only a small impact on forecast evolution. In **Figure 3.1**, the main contours show the T+120 forecasts of mean sea level pressure from Phase 2 of the parallel suite trial. These forecasts have been meaned over the verification period 12Z 13/11/95 to 12Z 02/12/95. The differences (trial-operational) have been superimposed on the chart, with negative

values shaded. This chart shows that differences in mean sea level pressure forecasts were fairly insignificant, even at T+120 with most being due to small changes in the depth and position of depressions. The addition of the new roughness fields in Phase 2 of the trial appeared to have little impact on mean sea level pressure. The largest difference shown on the chart at 65S 20E is associated with an area of low pressure which was slightly deeper in the trial forecasts. Over the Atlantic, variations were small, with the main feature being a slightly deeper trough over Newfoundland in the trial forecasts. Overall the subjective assessment worked out evenly between the trial and operational forecasts.

Comparing the trial and operational analyses, most variations were due to small differences in the calculation of mean sea level pressure over Antarctica. However, the largest difference, 5-10hPa, at 12Z 19th November over Antarctica, was probably due to data differences.

Some evidence of slight model instability over Antarctica were noticed during the trial but trial and operational forecasts were equally affected. A typical example is given in **FIGURE 3.2**, which compares the trial and operational T+24 forecasts from DT 12Z 09/11/95. On this chart, panel (c) shows the typical differences which indicate the noise in the fields over Antarctica.

The largest Atlantic difference between trial and operational mean sea level pressure forecasts at T+120 occurred in the last forecast of the trial from DT 12Z 27/11/95. The large dipole (-28/+23) shown in **FIGURE 3.3c** was due to the difference in the forecast position of a deep depression near Iceland. The trial depression, **FIGURE 3.3a**, was slightly deeper and centred further north and closer to Iceland than the operational depression, **FIGURE 3.3b**. In this case, the operational forecast was closer to the verifying analysis for 12Z 02/12/95 (**FIGURE 3.3d**).

We have already mentioned above that the mean trough over Newfoundland during Phase 2 was slightly deeper in the trial forecasts and the charts in **FIGURE 3.4** illustrate this point. The analysis for 12Z 26/11/95, **FIGURE 3.4d**, shows a depression, 993hPa, centred south of Nova Scotia. Both the trial and operational forecasts, compared in **FIGURES 3.4 a** and **b** respectively, predicted the position of this depression very accurately at T+120 but the trial depression was 6hPa deeper and closer to the analysed depth.

Differences of 10hPa between trial and operational forecasts tended to occur more frequently in the southern hemisphere but most were changes in detail rather than evolution. A typical example is shown in **FIGURE 3.5** of the small differences in position and depth between trial (**FIGURE 3.5a**) and operational (**FIGURE 3.5b**) forecasts of a depression at T+120 centred at 60S 77E. In this case, the operational depression was deeper and closer to the analysed centre.

3.2 IMPACT ON UPPER WINDS

A comparison of trial and operational 250hPa forecasts indicated that running with the 3CV physics had only a small impact on forecast jets, particularly in the northern hemisphere. In **FIGURE 3.6**, the main contours show the forecast 250hPa wind isotachs for T+24 from Phase 2 of the parallel suite trial. These forecasts have been meaned over the verification period 12Z 09/11/95 to 12Z 28/12/95 and the shaded areas indicate the wind vector differences (trial - operational). The main impact at T+24 was seen in the tropics, especially in the Pacific Ocean west of South America. The main differences were seen in the slight strengthening of the light winds in the tropics and on the equator side of the subtropical jets. However, these differences were too small to verify with confidence. **FIGURE 3.7** is a similar chart to **FIGURE 3.6** but for T+72. At T+72 the impact was still small but more widespread, as shown in **FIGURE 3.7.** There is evidence of a slight impact on the subtropical jet in the northern hemisphere over the Pacific Ocean and across America but differences were small.

The next two charts illustrate typical small differences seen between trial and operational jets at 250hPa. In **FIGURE 3.8a**, we see a comparison of the trial (a) and operational (b) T+24 forecast 250hPa jets across America verifying at 12Z 30/10/95. The differences are small but the trial jet in the south across Louisiana is slightly broader and further north. The analysis, **FIGURE 3.8d**, indicates that both jets were too strong on this occasion.

In **FIGURE 3.9**, we compare trial and operational 250hPa jets in the tropics over the Pacific Ocean west of South America. The impact of the trial, **FIGURE 3.9a**, was to increase the strength of the jet core over the Pacific. The verifying analysis, **FIGURE 3.9d**, was slightly closer to the operational forecast, **FIGURE 3.9b**.

FIGURE 3.10 compares the zonal mean cross-sections at T+24 of the U wind component on 12 standard levels between 1000hpa and 10hPa. These forecasts have been meaned over the Phase 2 period from 12Z 09/11/95 to 12Z 28/12/95. The difference chart, **FIGURE 3.10c**, confirms the subjective impression that the main impact at T+24 was over the equator.

FIGURE 3.11 compares the same cross-sections at T+120. The differences are more widespread, showing a small increase on the pole side of the subtropical jet at 30-40N and a similar increase in the branch of the subtropical jet in the southern hemisphere tropics over the Pacific and South America.

3.3 IMPACT ON TEMPERATURES

FIGURES 3.12 and 3.13 compare the zonal mean temperature cross-sections at T+24 and T+120 respectively on 12 standard levels between 1000 and 10hPa. These forecasts have been meaned over the Phase 2 period from DT 12Z 08/11/95 to DT12Z 27/12/95. The T+24 difference chart, **FIGURE 3.12c** indicates that the early impact on the temperatures was small, with the main features being a slight warming at 500hPa over the equator and at 850hPa in the southern hemisphere but also a small cooling at 700hPa in the southern tropics and also near the surface notably in the northern hemisphere.

The T+120 difference chart, **FIGURE 3.13c**, shows a small, beneficial warming in the northern hemisphere above 850hPa north of 45N due to a reduction in upper cloud. The cooling near the surface at high latitudes is due to a small increase of low cloud in lowest level. The warming in the southern hemisphere centred on 850hPa is due to a reduction of cloud at stratocumulus levels.

The surface cooling in the northern hemisphere is shown more clearly in **FIGURE 3.14**, where the 1.5m temperature differences have been meaned over Phase 2 of the trial. This surface cooling is related to a small increase in low cloud at high latitudes, but elsewhere to the boundary layer changes.

3.4 IMPACT ON CLOUD

TABLE 3.1
Comparison of mean cloud fractions in Phase 2 of the trial

Mean low cloud fraction	T+24 3CV / oper	T+72 3CV / oper	T+120 3CV / oper
N.Hem (90N-30N)	0.295 / 0.282	0.302 / 0.289	0.305 / 0.292
Tropics (30N-30S)	0.103 / 0.099	0.107 / 0.107	0.107 / 0.108
S.Hem (30S-90S)	0.363 / 0.371	0.356 / 0.368	0.356 / 0.363
Area 2	0.341 / 0.332	0.347 / 0.343	0.352 / 0.348
Mean medium cloud fraction			
N.Hem (90N-30N)	0.255 / 0.289	0.262 / 0.301	0.261 / 0.303
Tropics (30N-30S)	0.055 / 0.065	0.060 / 0.070	0.067 / 0.083
S.Hem (30S-90S)	0.227 / 0.265	0.243 / 0.294	0.244 / 0.296
Area 2	0.276 / 0.317	0.284 / 0.328	0.283 / 0.330
Mean high cloud fraction			
N.Hem (90N-30N)	0.305 / 0.331	0.315 / 0.342	0.316 / 0.344
Tropics (30N-30S)	0.228 / 0.239	0.250 / 0.259	0.262 / 0.269
S.Hem (30S-90S)	0.249 / 0.272	0.261 / 0.284	0.267 / 0.290
Area 2	0.333 / 0.360	0.355 / 0.382	0.359 / 0.387

Table 3.1 indicates an overall small increase in the mean low cloud of ~4% in the northern hemisphere at T+120 in the trial forecasts in Phase 2 compared to the operational forecasts. **FIGURE 3.15** indicates that most of this increase is at high latitudes and related to an increase in ice cloud in model level 1. There is a redistribution of low cloud in the Pacific Ocean west of South America and also an increase in low cloud off the west coast of Africa.

All the individual trial forecasts showed a noticeable decrease in medium cloud and the figures in Table 3.1 show that there was an overall decrease of 10-15% in the mean medium cloud fraction. **FIGURE 3.16** shows that the decrease in the southern hemisphere was associated mainly with the storm tracks over the oceans. **FIGURE 3.17** shows the overall slight decrease in mean high cloud of 7-8%.

FIGURE 3.18 compares the zonal mean cloud cross-sections of the trial and operational T+72 forecasts averaged over Phase 2 of the trial. The difference chart, **FIGURE 3.18c**, shows the increase of low cloud near the surface at high latitudes. The largest increase was 0.25 over the north pole and explains some of the cooling near the surface.

FIGURE 3.19 compares the zonal mean relative humidity cross-sections at T+72 respectively on 5 standard levels between 1000 and 500 hPa. The decrease in upper cloud referred to earlier occurred in the lowest model level allotted to medium cloud, ie levels 5-6. Above these levels, decreases in cloud and relative humidity were slight. The decrease in low cloud seen in the southern hemisphere at 60S occurred in level 3.

3.5 IMPACT ON PRECIPITATION

The mean convective precipitation differences for T+72 for phase 2 of the parallel suite trial are shown in **FIGURE 3.20**, with the shaded areas indicating an increase in the 72-hour accumulation and the contours a decrease in accumulation. This chart indicates that the differences in convective precipitation were mainly in the tropics, with the biggest impact in the South China Sea. Table 3.2 indicates a small overall increase in convective precipitation in the Tropics with negligible differences elsewhere.

TABLE 3.2.

Comparison of total mean global forecast precipitation accumulations for Phase 2 of the parallel suite trial.

Mean precipitation at T+24 (k/m^2/day)	Convective Accumulation 3CV / OPER	Dynamic Accumulation 3CV / OPER
N.Hem (90N - 30N)	1.118 / 1.120	1.969 / 1.985
Tropics (30N - 30S)	4.471 / 4.408	0.188 / 0.182
S.Hem (30S - 90S)	0.692 / 0.694	1.607 / 1.636
Area 2	1.522 / 1.523	2.120 / 2.116
Mean precipitation at T+72 (k/m^2/day)	Convective Accumulation 3CV / OPER	Dynamic Accumulation 3CV / OPER
N.Hem (90N - 30N)	3.014 / 3.027	5.279 / 5.328
Tropics (30N - 30S)	11.322 / 11.238	0.428 / 0.414
S.Hem (30S - 90S)	1.896 / 1.912	4.333 / 4.403
Area 2	4.202 / 4.230	5.736 / 5.735

The mean dynamic precipitation differences for T+72 for phase 2 of the parallel suite trial are shown in **FIGURE 3.21**, with the shaded areas indicating an increase in the 72-hour accumulation and the contours a decrease in accumulation. Small differences at high latitudes

in the northern hemisphere were due to changes in the ice fallout. **FIGURE 3.22** shows the differences in dynamic precipitation in greater detail over the U.K. and Scandinavia. Changes over the U.K. were small, showing a slight increase over the coast and also a slight spreading out of the peak accumulation over high ground, helping to reduce the model's rain shadow area over eastern Scotland.

3.6 IMPACT ON SURFACE WIND

Differences in the surface winds due to the new roughness fields were too small to be assessed subjectively. However, there was a small impact on the analyses as shown in **FIGURE 3.23 a** and **b**. These figures show the differences in the 10m wind between the trial and operational analyses, meaned over Phase 2 of the trial.

3.7 SUMMARY OF CONCLUSIONS FROM THE SUBJECTIVE ASSESSMENT OF THE GLOBAL MODEL.

- Overall the subjective assessment was neutral for the global model trial.
- Evolution changes were minimal apart from a slight deepening of the Newfoundland trough at T+120 in Phase 2.
- The new orographic roughness ancillary files had a slight impact on the 10m winds but the differences were too small to assess.
- At T+24, the main impact on 250hPa winds was seen in the Tropics, with a slight strengthening of the winds. At T+72, there was a slight strengthening of the subtropical jet at 30-40N which was beneficial. A similar strengthening of the jet in the southern hemisphere Tropics over the Pacific and South America seemed overdone.
- The slight warming in the northern hemisphere between 850hPa and 500hPa was beneficial but the surface cooling was detrimental.
- The increased low cloud at model level 1 at high latitudes associated with light snow did not seem excessive.
- The decrease in low/medium level cloud (model levels 4-6) associated with the southern hemisphere storm track was beneficial.
- there was a slight increase in convective precipitation in the tropics.

4 SUBJECTIVE ASSESSMENT OF THE LIMITED AREA MODEL TRIAL

4.1 INTRODUCTION

Large differences in surface temperature and cloud between trial and operational forecasts over Spitzbergen and the Barents Sea were found to be due to a mismatch of the trial and operational ice fields rather than due to the third climate physics . The ice fields in the trial limited area model analyses were not updated after November 15th . The ice analyses for 00Z 23rd November are compared in **FIGURE 4.1**, showing the greater area of ice in the operational analysis. For this reason, differences in this region have been discounted.

4.2 IMPACT ON FORECAST EVOLUTION

Differences between trial and operational forecasts were more noticeable with the limited area model at T+36 than with the global model at the same time and there was a tendency for trial depressions to be slightly deeper. However, the differences were still small with no changes of evolution. In **FIGURES 4.1 a** and **b**, we compare the trial and operational mean sea level pressure forecasts for T+36 respectively, averaged over Phase 2 of the trial from DT 00Z 14/11/95 to DT 00Z 28/11/95. The main feature noticed in the difference chart, **FIGURE 4.1c,** is a negative anomaly just south of Newfoundland, indicating that the Newfoundland trough was slightly deeper in the trial forecasts. The negative anomaly over Spitzbergen and the Barents sea was due to the mismatch of the trial and operational ice fields.

We mentioned above that the mean trough over Newfoundland during Phase 2 was slightly deeper in the trial forecasts and the charts in **FIGURE 4.3** provide an example. The analysis for 12Z 26/11/95, **FIGURE 4.3c**, shows a depression centred south of Nova Scotia, depth 992hPa. A comparison of the trial and operational T+36 forecasts verifying at this time shows that the trial depression, **FIGURE 4.3a**, was slightly further north and 10hPa deeper. This was the largest difference seen during the trial but in this case, the operational depression was closer to the analysis.

'Tanya' was the last North Atlantic hurricane of the season, featuring in the regional forecast area between 28th October and 3rd November, moving northeast to be centred at 39N 28W before becoming extra-tropical. The trial and operational T+36 forecasts verifying at 12Z 30th October are compared in **FIGURE 4.4**. The trial forecast, **FIGURE 4.4a**, predicted the hurricane to be slightly deeper by 6hPa. This was probably advantageous since the verifying analysis, **FIGURE 4.4c**, may not have been accurate.

The charts in **FIGURE 4.5** illustrate the differences in mean sea level pressure seen close to the U.K. during Phase 2. The trial and operational forecasts were very similar but the depression over southwest Ireland was slightly deeper in the trial forecast (**FIGURE 4.5a**), with an extra contour 992hpa. This slight deepening was confirmed by the verifying analysis, **FIGURE 4.5c**.

4.3 IMPACT ON SURFACE WINDS

Differences between 10m winds in the trial and operational forecasts were small, and hence the impact due to the new roughness fields in Phase 2 could not be isolated from the third climate physics changes. However, small differences between the analyses shown in **FIGURE 4.6**, especially over western Norway, Wales, northwest Scotland and the Alps may be mainly attributed to the increased roughness lengths.

4.4 IMPACT ON SURFACE TEMPERATURES.

The impact on 1.5m temperatures in the LAM trial was more variable than in the global trial. **FIGURES 4.7a-d** show the differences between trial and operational 1.5m temperature forecasts at T+24/36. These temperature forecasts have been meaned over Phase 2, from DT 00Z 14/11/95 to DT 00Z 29/11/95. **FIGURES 4.7 a/c** indicate those areas which were colder

in the trial forecasts at T+24/36 respectively, namely Eastern Europe and Canada. The cooling is thought to be mainly due to the boundary layer correction. **FIGURES 4.7 b/d** indicate those areas which were warmer in the trial forecasts, mainly at high latitudes due to the difference in the ice fields.

4.5 IMPACT ON PRECIPITATION

Overall, the impact of the third climate physics on dynamic precipitation was small, with the statistics in Table 4.1 indicating a small decrease in the mean accumulation at T+36. The shading in **FIGURE 4.8a** indicates the areas where the mean dynamic precipitation was increased in the trial, whilst the shading in **FIGURE 4.8b** indicates the reverse. The main impact was positional, with the trial precipitation associated with the Newfoundland trough slightly further west. Over the U.K. the impact was a very slight increase over northwest Scotland. The statistics in Table 4.1 indicate that the overall mean dynamic precipitation was decreased very slightly ($\sim 1\%$).

The difference in convective precipitation was more obvious, with most individual forecasts indicating a small increase in convective rain over the warmer seas in the southwest of the LAM area. This increase is shown clearly by the shaded areas in **FIGURE 4.8c** and also by the statistics in Table 4.1 below. Generally, trial and operational rainfall forecasts for the U.K. were very similar but three examples of differences are described below.

TABLE 4.1

Trial and operational mean precipitation averaged over Phase 2 from DT 00Z 14/11/95 to DT 00Z 28/11/95.

Mean precipitation	Convective precipitation 3CV / oper	Dynamic precipitation 3CV / oper
T+12	0.785 / 0.679	0.880 / 0.896
T+24	1.427 / 1.219	1.622 / 1.644
T+36	2.091 / 1.783	2.383 / 2.400

(i) T+18 FORECAST VERIFYING 18Z 20/11/95

In a southerly airstream over the U.K., the trial T+18 forecast, **FIGURE 4.9c**, predicted light showers to be more widespread over Wales, southwest England and the Midlands. The weather was predominantly cloudy and patchy light rain was reported in many places, principally in the west as indicated by the radar, **FIGURE 4.9a.** The trial forecast of increased showers was justified.

(ii) T+30 FORECAST VERIFYING 06Z 23/11/95

The radar for 06Z, **FIGURE 4.10a**, shows that the heaviest and most persistent rain occurred over northwest Scotland but elsewhere it was dry apart from intermittent light rain and

drizzle over western coasts and hills. The operational forecast, FIGURE **4.10b**, light rain/showers to be too widespread over wales and northern England. The trial forecast of occasional light drizzle was better.

(iii) T+36 FORECAST VERIFYING 12Z 25/11/95

The radar for 12Z, **FIGURE 4.11a**, shows an area of persistent, moderate rain over southeast England associated with a wave on a cold front. The operational T+36 forecast, **FIGURE 4.11b**, predicted the wave to be over northwest France, which was too slow. The trial, **FIGURE 4.11c**, predicted more widespread showers over southern England, thereby giving a slightly better forecast.

4.6 IMPACT ON CLOUD.

FIGURES 4.12 a-c indicate the differences in low, medium and high cloud at T+36 averaged over Phase 2 of the trial from DT 00Z 14/11/95 to DT 00Z 28/11/95. In each chart, the shaded areas indicate a decrease in the mean cloud fraction in the trial forecasts. Overall, there was hardly any change in the mean low cloud fraction as the statistics in Table 4.2 below indicate. Locally, **FIGURE 4.12a** shows that there was a small decrease in the mean low cloud over the North Sea and over Eastern Europe. The biggest signal was from the medium cloud, with the statistics in Table 4.2 indicating a decrease in the mean medium level cloud from 0.26 to 0.23, representing a reduction of 10-11% in the trial forecasts. This decrease in medium cloud was not associated with frontal zones but with the cloudy northeasterly flow just west of the British Isles. Global model cross sections indicated that the medium cloud reduction was mostly at about 800hPa, the bottom level for medium cloud. The signal from the high cloud was mixed, with **FIGURE 4.12c** indicating small local changes in the distribution. Overall, there was a small decrease in the mean high cloud fraction from 0.34 to 0.32.

TABLE 4.2

Trial and operational low, medium and high cloud fractions averaged over Phase 2 from DT 00Z 14/11/95 to DT 00Z 28/11/95.

Mean cloud fraction	3rd climate version physics	operational version
Low cloud T+36	0.2605	0.2598
Medium cloud T+36	0.2289	0.2559
High cloud T+36	0.3224	0.3372

Two forecast cloud comparisons are described below. In the model cloud charts, small circles (o) represent medium cloud fractions >0.5 and small dots (.) represent low cloud fractions >0.5. Comparing the trial and operational forecasts during the trial, it was apparent that small differences in humidity had quite a large impact on forecast cloud output.

In the first example, **FIGURES 4.13a** and **b** compare the T+36 operational and trial cloud

forecasts for 12Z 24/11/95. In the trial forecast, **FIGURE 4.13b**, there is a marked reduction in the amount of low cloud predicted at about 55N 15-25W in the unstable northeasterly airstream west of the depression. This was correct, since the cloud in this region was mainly convective. A comparison of model ascents for 55N 25W showed that the operational ascent, **FIGURE 4.13c**, was moister at 900hPa.

In the second example, **FIGURES 4.14a** and **b** compare the T+24 operational and trial cloud forecasts for 00Z 27/11/95. There is a clear decrease in medium cloud in the trial forecast (**FIGURE 4.14b**) between 20-30W, to the west of the depression. This decrease seemed rather overdone, since meteosat satellite imagery indicated some thin layer cloud in this region. If we compare the operational and trial model ascents at 50N 25W, in **FIGURES 4.14c** and **d** respectively, then the different cloud structure is a result of small changes in humidity, with the operational ascent moister above 800hPa and the trial ascent saturated at ~900hPa.

4.7 SUMMARY OF CONCLUSIONS FROM THE SUBJECTIVE ASSESSMENT OF THE LIMITED AREA MODEL TRIAL.

- The subjective assessment was neutral for the limited area model trial.
- Evolution changes were minimal apart from a slight deepening of depressions.
- The 3CV changes were slightly sensitive to model resolution since differences at T+36 were larger in the limited area model than in the global model.
- The new orographic ancillary files had a small impact on the 10m wind but differences were too small to assess.
- Differences in the 250hPa jets in the Atlantic were very small at T+24/36.
- There was a slight surface cooling over Eastern Europe and Canada.
- There was a noticeable decrease in medium cloud in the eastern Atlantic which was sometimes correct, sometimes incorrect.
- Trial and operational rainfall forecasts over the U.K. were very similar. The few differences which occurred favoured the trial.
- There was a slight increase in convective rain over the sea in the southwest of the area.

5 DISCUSSION

The results of the parallel trial suggest that the implementation of this package will lead to a neutral impact on the operational NWP models. Both the objective and subjective assessments are consistent with the earlier findings of Milton & Lorrimer (1995) and Evans (1996). To summarise, the main positive impacts are:

- Improved geopotential heights and temperatures.
- Improved relative humidities.
- Improved winds in the extra-tropics
- Improved PMSL.
- Improved 10m winds in the global model.
- Slight improvement in precipitation forecasts.

There is only one major deterioration:

- The 1.5m temperatures deteriorate in both the LAM and global model, despite the existing biases being in opposite senses.

The overall neutral impact of this study is further shown by a study of the tropical cyclone forecast track verification (see appendix A4).

A further disadvantage is the cost of the package, particularly LPPN. This increases the cost of the large scale precipitation section by an order of magnitude and the total run time by ~15%. However, using aggressive optimization reduces this so that the total run time is only increased by 3-4%.

Despite the neutral impact of this package, it is found to be beneficial in the climate model and so we recommend that it should be implemented operationally. Approval for the change was given and the package was implemented operationally on 16th January 1996.

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A1 FIGURE CAPTIONS

Figure 2.1 The geopotential height bias and RMS error in the NH against upper air soundings at T+24 (upper panels) and T+120 (lower panels). The trial results (broken line) are generally better than the operational results (solid line) by between 0.5m at T+24 and 3m at T+120.

Figure 2.2 The geopotential height bias and RMS error in area 2 against upper air soundings at T+72 (upper panels) and T+120 (lower panels). Below 500hPa the trial results (broken line) are worse than the operational results (solid line) by ~1m.

Figure 2.3 The temperature bias and RMS error at T+120 in the NH and SH (lower panels) against upper air soundings. Below 500hPa the trial results (broken line) are typically better than the operational results (solid line) by 0.1-0.2K.

Figure 2.4 The relative humidity bias and RMS error at T+120 in the tropics against upper air soundings. This is the first time at which either of these areas show any significant improvement.

Figure 2.5 The vector wind bias and RMS error at T+120 in the NH (upper panels), in the tropics (centre panels) and the SH (lower panels) against upper air soundings. The biases are generally 0.1-0.05ms^{-1} smaller in the trial.

Figure 2.6 The temperature bias and RMS error in the NH at T+24 (upper panels) and T+120 (lower panels) against air reps. The trial shows a small improvement in the bias at high levels and early times. As the forecast progresses this propagates downwards and increases.

Figure 2.7 The percentage change in the RMS temperature error against air reps in area 2 and the SH at T+120. A negative value indicates that the trial is better. In this case the trial RMS error is around 2% smaller.

Figure 2.8 The vector wind bias and RMS error in the tropics at T+24 (upper panels) and T+120 (lower panels) against air reps. At T+24 there is an improvement in the bias of 0.1ms^{-1}. However, by T+120, the winds have strengthened by 0.2ms^{-1}. This keeps the magnitude of the bias the same, but changes its sign.

Figure 2.9 The percentage change in the RMS temperature error against AMDARs at T+120 in the NH (left) and SH (right). The RMS improves by around 2-4%.

Figure 2.10 The PMSL bias and RMS error against surface observations as a function of forecast range. In area 2 and the tropics there is a reduction in the bias, whilst in the NH and SH the bias deteriorates.

Figure 2.11 The percentage change in the RMS PMSL error against surface observations as a function of forecast range. Late in the forecast there are improvements of up to 2%.

Figure 2.12 The 10m vector wind bias and RMS error in area 2, the NH, the tropics and the SH against surface observations. There is a weakening of the winds which is generally beneficial, with the notable exception of the SH (bottom panel).

Figure 2.13 The 1.5m temperature bias and RMS error in area 2, the NH, the tropics, and the SH error against surface observations as a function of forecast range. In all areas the bias deteriorates by 0.1-0.2K and the RMS is 10% worse at T+24.

Figure 2.14 The PMSL bias and RMS error in the NH and the tropics against analysis as a function of forecast range. There is a beneficial change in the pressure bias of up to 5Pa, while the RMS error reduces by about 1.5%.

Figure 2.15 The geopotential height bias and RMS error in the NH and the tropics against analysis at T+120. The trial height bias (dashed line) is about 1m greater than the operational bias (solid line). This is beneficial except in the NH (and area 2 - not shown) below 500hPa, where the bias is already positive. The RMS error reduces by up to 6%, especially at upper levels.

Figure 2.16 The temperature bias and RMS error in the NH and the tropics against analysis at T+120. Below 500hPa, the trial temperature bias (dashed line) is about 0.1K smaller than the operational bias (solid line).

Figure 2.17 The percentage impact on the RMS temperature error at 850hPa in the NH and the tropics against analysis as a function of forecast range. At early times the trial is worse than the operational set-up (positive changes), but by T+120 the change is generally neutral or a slight improvement.

Figure 2.18 The percentage impact on the RMS relative humidity error at 950hPa in the tropics against analysis as a function of forecast range. At T+24 the trial is worse than the operational set-up (positive changes) by almost 20%, but by T+120 the trial is only 2% worse.

Figure 2.19 The vector wind bias and RMS error in the NH and the SH against analysis at T+120. The trial wind bias (dashed line) is about 0.05-0.1ms^{-1} stronger than the operational bias (solid line). This is beneficial in the NH and area 2. In the SH and the tropics, the bias is already positive, and so the change is detrimental.

Figure 2.20 The 10m vector wind bias and RMS error in area 2 and the NH against analysis as a function of forecast range. The trial wind bias (dashed line) is about up to 0.05ms^{-1} weaker than the operational bias (solid line). This is beneficial in all areas except area 2, where the change is neutral. There is no significant change in the RMS scores.

Figure 2.21 The 1.5m temperature bias and RMS error in the NH and the tropics against analysis as a function of forecast range. As the in the verification against surface observations the trial bias (dashed line) is significantly colder than the operational bias (solid line).

Figure 2.22 The LAM geopotential height bias and RMS error at T+12 and T+36, verified against upper air reports. The trial bias (dashed line) is 0.5m greater (or more positive) at T+12 and 3m greater by T+36.

Figure 2.23 The percentage impact on the RMS error in the LAM forecast of geopotential height over UK & Iceland, verified against upper air reports. At T+12 the trial errors are 1-2% worse, but by T+36 they have improved by up to 4%.

Figure 2.24 The LAM temperature bias and RMS error at T+24, verified against upper air reports. The trial bias (dashed line) is up to 0.5K warmer.

Figure 2.25 The percentage impact on the RMS error in the LAM forecast of temperature over UK & Iceland at T+36, verified against upper air reports. The RMS error at 850hPa has improved by almost 4%.

Figure 2.26 The LAM relative humidity bias and RMS error at T+12 and T+36. The trial bias (dashed line) is 1% drier at T+12 and 850hPa, verified against upper air reports. By T+36 this beneficial drying has increased to 1.5% and propagated upwards.

Figure 2.27 The LAM vector wind bias and RMS error at T+12 and T+36 over the UK and Iceland, verified against upper air reports. The trial bias (dashed line) is 0.1ms^{-1} weaker at T+12, but stronger by similar amount at T+36. At T+36 the trial RMS has deteriorated by 0.5ms^{-1}.

Figure 2.28 The LAM PMSL bias and RMS error over the UK and Iceland as a function of forecast range, verified against surface observations. The trial bias (dashed line) is reduced by up to 20Pa.

Figure 2.29 The LAM 1.5m temperature bias and RMS error over the UK and Iceland as a function of forecast range, verified against surface observations. The trial bias (dashed line) is warmed by 0.4K, which is detrimental. Also, the RMS error deteriorates by 4-12%.

Figure 2.30 The LAM 10m wind bias and RMS error as a function of forecast range, verified against surface observations. The trial bias (dashed line) has strengthened by 0.15ms^{-1}.

Figure 2.31 The LAM PMSL bias and RMS error as a function of forecast range, verified against analyses. The trial bias (dashed line) is reduced by up to 20Pa, which is detrimental at T+24 and T+36.

Figure 2.32 The percentage impact on the RMS error in the LAM forecast of PMSL, verified against analyses. There are deteriorations in the trial of up to 7%.

Figure 2.33 The LAM geopotential height bias and RMS error at T+12, T+24 and T+36, verified against analyses. The trial bias (dashed line) is 2m greater (or more positive) than the operational bias (solid line). This is generally beneficial, except below 400hPa at T+12.

Figure 2.34 The percentage impact on the RMS error in the LAM forecast of geopotential height over UK and Iceland at T+12 and T+24, verified against analyses. The impact ranges from +10% to -10%.

Figure 2.35 The LAM temperature bias and RMS error at T+24 and T+36, verified against analyses. The trial bias (dashed line) is up to 0.5K warmer than the operational bias (solid line) below 500hPa. This is largely beneficial, except near the surface, where the cold bias becomes a warm bias.

Figure 2.36 The LAM 1.5m temperature bias and RMS error as a function of forecast range, verified against analyses. The trial bias (dashed line) is significantly, and detrimentally, warmer.

Figure 2.37 The LAM relative humidity bias and RMS error at T+36, verified against analyses, for the full LAM area and over UK and Iceland. The trial bias (dashed line) is up to 2% dryer than the operational bias (solid line). This is largely beneficial, although the change for the full area is a little excessive at 850hPa. However, the error is already small here.

Figure 2.38 The LAM vector wind bias and RMS error at T+12 and T+24, verified against analyses. The trial bias (dashed line) is weaker at T+12, but stronger at T+24. The strengthening in the later forecast is beneficial above 800hPa.

Figure 2.39 The LAM 10m wind bias and RMS error as a function of forecast range, verified against analyses. The trial bias (dashed line) is significantly, and detrimentally, stronger. This is also apparent in the RMS.

Figure 2.40 The LAM 10m wind speed bias as a function of forecast range at four surface stations and averaged over phase 2. The trial bias (dashed line) is improved at Wick, Aberdeen and Shawbury, all of which lie to the east of areas affected by the changes to the orographic roughness ancillary files. Guernsey, which is not close to any regions which have changed, shows a deterioration in the bias.

Figure 3.1 T+120 mean sea level pressure forecasts from the parallel suite trial meaned over Phase 2, verifying period 12Z 13/11/95 to 12Z 02/12/95. Trial - operational differences superimposed.

Figure 3.2 T+24 mean sea level pressure forecasts verifying 12Z 10/11/95. (a). Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.3 T+120 mean sea level pressure forecasts verifying 12Z 02/12/95. (a). Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.4 T+120 mean sea level pressure forecasts verifying 12Z 26/11/95. (a). Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.5 T+120 mean sea level pressure forecasts verifying 12Z 22/11/95. (a). Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.6 T+24 250hPa wind forecasts from the parallel suite trial meaned over Phase 2, verifying period 12Z 09/11/95 to 12Z 28/11/95. Trial - operational vectors differences superimposed.

Figure 3.7 T+72 250hPa wind forecasts from the parallel suite trial meaned over Phase 2, verifying period 12Z 11/11/95 to 12Z 30/11/95. Trial - operational vectors differences superimposed.

Figure 3.8 T+24 250hPa wind forecast over America verifying at 12Z 29/10/95 (a). Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.8 T+24 250hPa wind forecast over America verifying at 12Z 29/10/95 (a). Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.9 T+24 250hPa wind forecast over Pacific and South America verifying at 12Z 29/10/95. (a) Parallel suite trial (b). Operational (c). Trial - operational difference (d) Verifying analysis

Figure 3.10 Zonal mean wind cross-sections of the U component for T+24 from Phase 2 of the parallel suite trial, verifying period 12Z 09/11/95 to 12Z 28/11/95. Cross -section on 12 standard levels from 1000hPa to 10hPa. (a) Trial (b) Operational (c) Trial - Operational

Figure 3.11 Zonal mean wind cross-sections of the U component for T+120 from Phase 2 of the parallel suite trial, verifying period 12Z 13/11/95 to 12Z 02/12/95. Cross -section on 12 standard levels from 1000hPa to 10hPa. (a) Trial (b) Operational (c) Trial - Operational

Figure 3.12 Zonal mean temperature cross-sections for T+24 from Phase 2 of the parallel suite trial, verifying period 12Z 09/11/95 to 12Z 28/11/95. (a) Trial (b) Operational (c) Trial - Operational

Figure 3.13 Zonal mean temperature cross-sections for T+120 from Phase 2 of the parallel suite trial, verifying period 12Z 13/11/95 to 12Z 02/12/95. Cross -section on 12 standard levels from 1000hPa to 10hPa. (a) Trial (b) Operational (c) Trial - Operational

Figure 3.14 T+120 1.5m temperature forecasts from the parallel suite trial meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. Trial - operational differences superimposed.

Figure 3.15 T+120 low cloud forecasts from the parallel suite trial meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. Trial - operational differences superimposed.

Figure 3.16 T+120 medium cloud forecasts from the parallel suite trial meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. Trial - operational differences superimposed.

Figure 3.17 T+120 high cloud forecasts from the parallel suite trial meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. Trial - operational differences superimposed.

Figure 3.18 Zonal mean cloud cross-sections on model levels 1-16 at T+72 meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. (a) Trial (b) Operational c) Trial - Operational differences.

Figure 3.19 Zonal mean relative humidity cross-sections for T+72 from Phase 2 of the parallel suite trial, DT12Z 08/11/95 to DT12Z 27/11/95. Cross -section on 5 standard levels from 1000hPa to 500hPa. (a) Trial (b) Operational (c) Trial - Operational

Figure 3.20 Convective precipitation forecast differences at T+72 meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95.

Figure 3.21 Dynamic precipitation forecast differences at T+72 meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95.

Figure 3.22 Dynamic precipitation forecast differences at T+72 meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. (a) U.K. and Scandinavia

Figure 3.23 Surface wind analysis from the parallel suite trial meaned over Phase 2, DT12Z 08/11/95 to 12Z 27/11/95. Trial - operational differences superimposed.

Figure 4.1 Sea ice analysis in the limited area model for 00Z 23/11/95: (a) operational (b) trial

Figure 4.2 T+36 mean sea level pressure forecasts meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95: (a) trial (b) operational (c) trial - operational differences

Figure 4.3 T+36 mean sea level pressure forecast DT 00Z 25/11/95 VT 12Z 26/11/95: (a) trial (b) operational (c) verifying analysis for 12Z 26/11/95 (d) trial - operational differences

Figure 4.4 T+36 mean sea level pressure forecast DT 00Z 29/10/95 VT 12Z 30/10/95: (a) trial (b) operational (c) verifying analysis for 12Z 30/10/95 (d) trial - operational differences

Figure 4.5 T+36 mean sea level pressure forecast DT 00Z 23/11/95 VT 12Z 24/11/95: (a) trial (b) operational (c) verifying analysis for 12Z 24/11/95

Figure 4.6 10m wind analysis differences (trial - operational) meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95

Figure 4.7 Forecast 1.5m temperature differences (trial - operational) meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95: (a) T+24 shaded area indicates trial colder (b) T+24 shaded area indicates trial warmer; (c) T+36 shaded area indicates trial colder (b) T+36 shaded area indicates trial warmer

Figure 4.8 (a) Forecast dynamic precipitation differences at T+36 meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95. Shaded area denotes trial increase; (b) Forecast dynamic precipitation differences at T+36 meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95. Shaded area denotes trial decrease; (c) Forecast convective precipitation differences at T+36 meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95. Shaded area denotes trial increase

Figure 4.9 (a) Radar for 18Z 20/11/95 (b) operational forecast total precipitation rates DT 00Z 20/11/95 VT 18Z 20/11/95 (c) trial forecast total precipitation rates DT 00Z 20/11/95 VT 18Z 20/11/95

Figure 4.10 (a) Radar for 06Z 23/11/95 (b) operational forecast total precipitation rates DT 00Z 22/11/95 VT 06Z 23/11/95 (c) trial forecast total precipitation rates DT 00Z 22/11/95 VT 06Z 23/11/95

Figure 4.11 (a) Radar for 12Z 25/11/95 (b) operational forecast total precipitation rates DT 00Z 24/11/95 VT 12Z 25/11/95 (c) trial forecast total precipitation rates DT 00Z 24/11/95 VT 12Z 25/11/95

Figure 4.12 Cloud differences (trial - operational) at T+36 meaned from DT 00Z 14/11/95 to DT 00Z 28/11/95. Trial cloud reduction shaded. (a) low cloud (b) medium cloud (c) high cloud

Figure 4.13 Cloud forecast for T+36, DT 00Z 23/11/95 VT 12Z 24/11/95: (o = >4 oktas medium cloud, . = > 4 oktas low cloud) (a) operational (b) trial (c) Operational forecast ascent for T+36 DT 00Z 23/11/95 VT 12Z 24/11/95 (d) Trial forecast ascent for T+36 DT 00Z 23/11/95 VT 12Z 24/11/95

Figure 4.14 Cloud forecast for T+24, DT 00Z 26/11/95 VT 00Z 27/11/95: (o = >4 oktas

medium cloud, . = > 4 oktas low cloud) (a) operational (b) trial (c) Operational forecast ascent for T+24 DT 00Z 26/11/95 VT 00Z 27/11/95 (d) Trial forecast ascent for T+24 DT 00Z 26/11/95 VT 00Z 27/11/95

A2 PRECIPITATION VERIFICATION STATIONS

03005	Lerwick
03008	Fair Isle
03017	Kirkwall Airport
03022	Benbecula
03026	Stornoway Airport
03049	Cape Wrath Lighthouse
03063	Aviemore
03066	Kinloss
03075	Wick
03091	Aberdeen/Dyce Airport
03100	Tiree
03102	Orsay Lighthouse
03135	Prestwick Airport
03140	Glasgow (Abbotsinch) Airport
03160	Edinburgh (Turhnouse) Airport
03162	Eskdalemuir
03171	Leuchars
03204	Ronaldsway Airport
03215	Aspatria
03222	Carlisle
03240	Boulmer
03257	Leeming
03262	Tynemouth
03302	Valley
03322	Aughton
03334	Manchester (Ringway) Airport
03360	Finningley
03391	Coningsby
03414	Shawbury
03452	?
03502	Aberporth
03521	Madley
03534	Birmingham (Elmdon) Airport
03566	Wyton
03586	Honington
03590	Wattisham
03609	Mumbles
03683	Stansted Airport
03707	Chivenor
03740	Lyneham
03761	Odiham

03772	London/Heathrow Airport
03776	London/Gatwick Airport
03808	Camborne
03817	St. Mawgan
03827	Plymouth
03853	Yeovilton
03894	Guernsey Airport
03905	Carrigans
03917	Belfast/Aldergrove Airport
03923	Glenanne
03953	Valentia Observatory
03957	Rosslare
03960	Kilkenny
03962	Shannon Airport
03969	Dublin Airport
03970	Claremorris
03971	Mullingar
03974	Clones
03976	Belmullet
03980	Malin Head

A3 PRECIPITATION VERIFICATION SCORES

The following tables give the false alarm rate (FAR), the probability of detection (POD), the frequency bias (FB), the threat score (TS) and the equitable threat score (ETS) for four rainfall categories: nil/trace (0-0.1mm), light (0.1-2mm), moderate (2.0-10mm) and heavy (>10mm). The scores are for periods of six hours. In the following definitions T is the total number of events, F_i is the of events forecast in class i, O_i is the number of events observed in class i and N_{ij} is the number of events forecast to be in class i when event j was observed. Thus, a 2 event contingency table would be:

	Event 1 observed	Event 2 observed	Total
Event 1 forecast	N_{11}	N_{12}	F_1
Event 2 forecast	N_{21}	N_{22}	F_2
Total	O_1	O_2	T

Then we can make the following definitions:

$$FAR(i) = 1 - \frac{N_{ii}}{O_i}$$

$$POD(i) = \frac{N_{ii}}{O_i}$$

$$FB(i) = \frac{F_i}{O_i}$$

$$TS(i) = \frac{N_{ii}}{F_i + O_i - N_{ii}}$$

$$ETS(i) = \frac{N_{ii} - \frac{O_i F_i}{T}}{O_i + F_i - N_{ii} - \frac{O_i F_i}{T}}$$

Using these definitions we have calculated the scores for the trial and the operational control. In the following tables the figure to the left of the slash is for the control, followed by the trial value.

TABLE A3.1

Comparison of trial and operational false alarm rates (FAR)

	Nil/trace	Light	Moderate	Heavy
T+6 - T+12	0.21/0.20	0.55/0.55	0.63/0.63	0.67/0.60
T+12 - T+18	0.11/0.14	0.64/0.64	0.61/0.59	0.87/0.78
T+18 - T+24	0.11/0.21	0.61/0.59	0.72/0.72	1.00/1.00
T+24 - T+30	0.20/0.22	0.69/0.69	0.68/0.69	0.50/0.62
T+30 - T+36	0.27/0.26	0.64/0.61	0.75/0.74	1.00/1.00

TABLE A3.2

Comparison of trial and operational probabilities of detection (POD)

	Nil/trace	Light	Moderate	Heavy
T+6 - T+12	0.63/0.59	0.57/0.57	0.49/0.56	0.11/0.20
T+12 - T+18	0.58/0.53	0.57/0.58	0.58/0.59	0.08/0.15
T+18 - T+24	0.53/0.56	0.56/0.53	0.38/0.40	0.00/0.00
T+24 - T+30	0.49/0.49	0.57/0.53	0.35/0.36	0.30/0.27
T+30 - T+36	0.44/0.47	0.55/0.55	0.38/0.40	0.00/0.00

TABLE A3.3

Comparison of trial and operational frequency biases (FB)

	Nil/trace	Light	Moderate	Heavy
T+6 - T+12	0.79/0.74	1.26/1.27	1.33/1.53	0.33/0.50
T+12 - T+18	0.66/0.62	1.60/1.61	1.48/1.44	0.62/0.69
T+18 - T+24	0.66/0.78	1.45/1.28	1.33/1.44	0.64/0.69
T+24 - T+30	0.61/0.63	1.84/1.71	1.09/1.18	0.60/0.73
T+30 - T+36	0.60/0.63	1.53/1.41	1.51/1.54	0.22/0.56

TABLE A3.4

Comparison of trial and operational threat scores (TS)

	Nil/trace	Light	Moderate	Heavy
T+6 - T+12	0.54/0.52	0.34/0.34	0.27/0.28	0.09/0.15
T+12 - T+18	0.54/0.49	0.28/0.29	0.30/0.32	0.05/0.10
T+18 - T+24	0.46/0.49	0.30/0.30	0.19/0.20	0.00/0.00
T+24 - T+30	0.43/0.43	0.25/0.24	0.20/0.20	0.23/0.19
T+30 - T+36	0.38/0.40	0.28/0.30	0.18/0.19	0.00/0.00

TABLE A3.5

Comparison of trial and operational equitable threat scores (ETS)

	Nil/trace	Light	Moderate	Heavy
T+6 - T+12	0.26/0.26	0.12/0.11	0.20/0.22	0.09/0.15
T+12 - T+18	0.27/0.24	0.10/0.09	0.23/0.24	0.04/0.09
T+18 - T+24	0.22/0.25	0.07/0.08	0.12/0.11	-0.01/-0.01
T+24 - T+30	0.17/0.17	0.05/0.05	0.13/0.11	0.23/0.18
T+30 - T+36	0.14/0.16	0.05/0.05	0.10/0.11	0.00/0.00

APPENDIX A4 TROPICAL CYCLONE FORECAST TRACK VERIFICATION

PARALLEL SUITE EXPERIMENT No.36

Tropical Cyclone Forecast Track Verification

1. Sponsor

Clive Wilson, NWP Division.

2. Description of Experiment

The parallel suite PG12 global model run used 3CV physics package. Also included new orography from 09.11.95 onwards.

3. Duration and Forecast Specification

The total period of the experiment was from 23.10.95 to 27.11.95
PS forecasts were run out to T+120 every 24 hours at 12Z.

4. Tropical Cyclone Forecast Verification

a) Differences in samples

The OS run DT 12Z 19.11.95 dissipated TC Agnielle by T+120; the corresponding PS run did not.

b) Verification Statistics

Total number of storms which were active during the period : **10**
Homogeneous samples were used in the statistical comparison

Forecast Error comparison for whole globe

	T+0	T+24	T+48	T+72	T+96	T+120
No. verified	47	35	26	19	15	11
Operational DPE	58	188	335	570	826	1178
Parallel Suite DPE	59	188	339	571	833	1201
% increase	1.7	0.0	1.2	0.2	0.8	2.0

No. verified : The number of forecasts verified for each forecast time
DPE : Direct Positional Error in kilometres
% increase : Percentage increase in PS analysis/forecast error compared to OS

The overall percentage increase in PS analysis/forecast error : +1.0%

Forecast Error comparison for North-West Pacific

	T+0	T+24	T+48	T+72	T+96	T+120
No. verified	26	20	16	13	11	9
Operational DPE	46	186	294	522	798	1147
Parallel Suite DPE	49	185	297	524	799	1169
% increase	6.5	-0.5	1.0	0.4	0.1	1.9

The overall percentage increase in PS analysis/forecast error : +2.1%

Forecast Error comparison for North Atlantic

	T+0	T+24	T+48	T+72	T+96	T+120
No. verified	6	3	1	0	0	0
Operational DPE	74	305	442	***	***	***
Parallel Suite DPE	72	275	435	***	***	***
% increase	-2.7	-9.8	-1.6	***	***	***

The overall percentage increase in PS analysis/forecast error : -4.7%

Forecast Error comparison for North Indian Basin

	T+0	T+24	T+48	T+72	T+96	T+120
No. verified	7	5	3	1	0	0
Operational DPE	56	201	576	1004	***	***
Parallel Suite DPE	63	208	596	1004	***	***
% increase	12.5	3.5	3.5	0.0	***	***

The overall percentage increase in PS analysis/forecast error : +7.2%

Forecast Error comparison for South-West Indian Basin

	T+0	T+24	T+48	T+72	T+96	T+120
No. verified	8	7	6	5	4	2
Operational DPE	83	136	306	607	900	1317
Parallel Suite DPE	80	144	305	607	925	1344
% increase	-3.6	5.9	-0.3	0.0	2.8	2.1

The overall percentage increase in PS analysis/forecast error : +0.8%

5. Comments

Including the new physics package resulted in an increase in global TC analysis and forecast positional errors of 1.0% on average. There was just one case when an OS forecast dissipated a storm earlier than the PS forecast. There were variabilities between the various basins, but sample sizes were too small to draw any conclusions from these differences.

Details of the formulation of the UKMO TC verification Scheme can be found in NWP Gazette Vol.1, No.2. December 1994.

Julian Heming, FS9

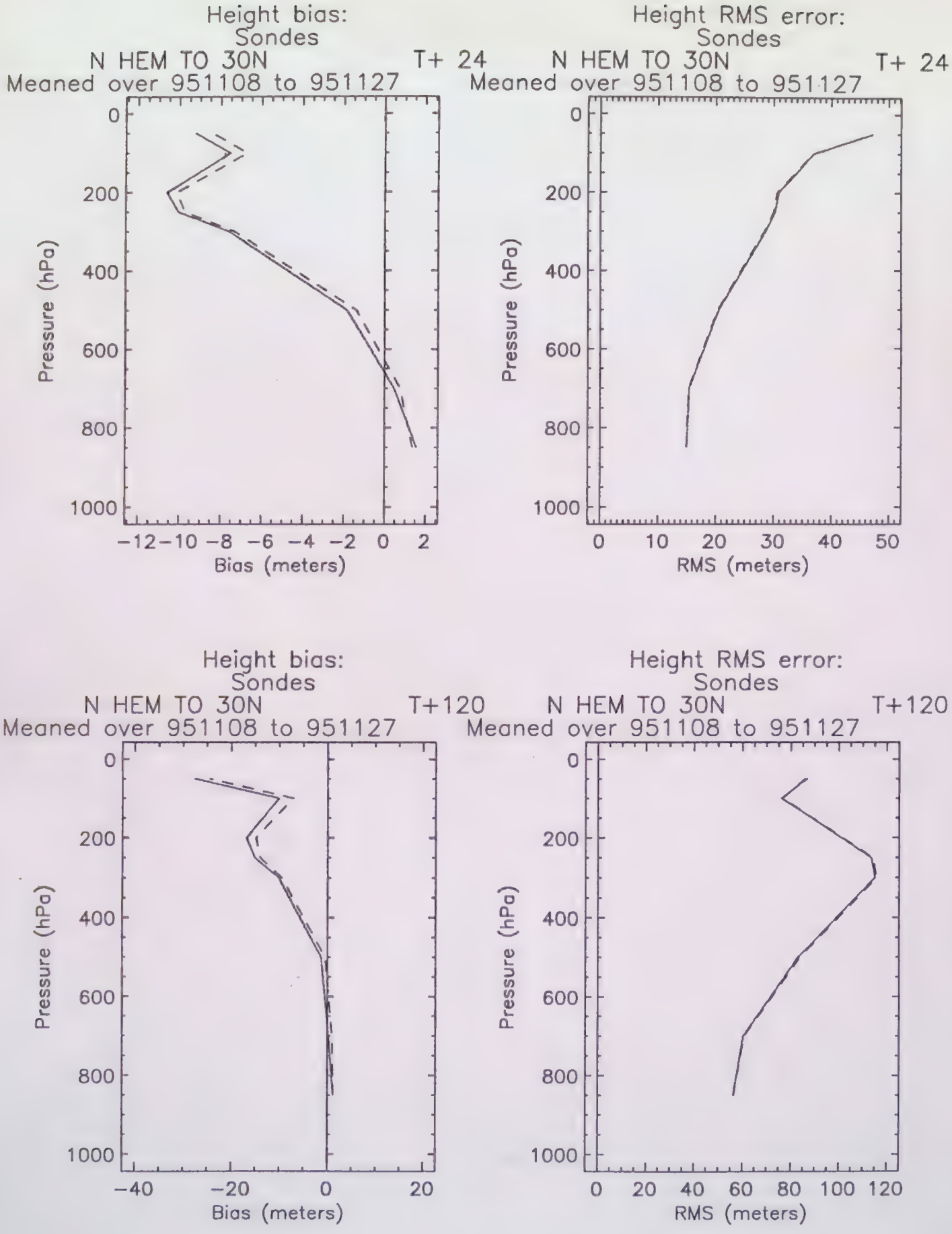

Height bias:
Sondes
N HEM TO 30N
T+ 24
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−12 −10 −8 −6 −4 −2 0 2
Bias (meters)
Height RMS error:
Sondes
N HEM TO 30N
T+ 24
Meaned over 951108 to 951127
Pressure (hPa)
0 10 20 30 40 50
RMS (meters)
Height bias:
Sondes
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
−40 −20 0 20
Bias (meters)
Height RMS error:
Sondes
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0 20 40 60 80 100 120
RMS (meters)

FIGURE 2. 1

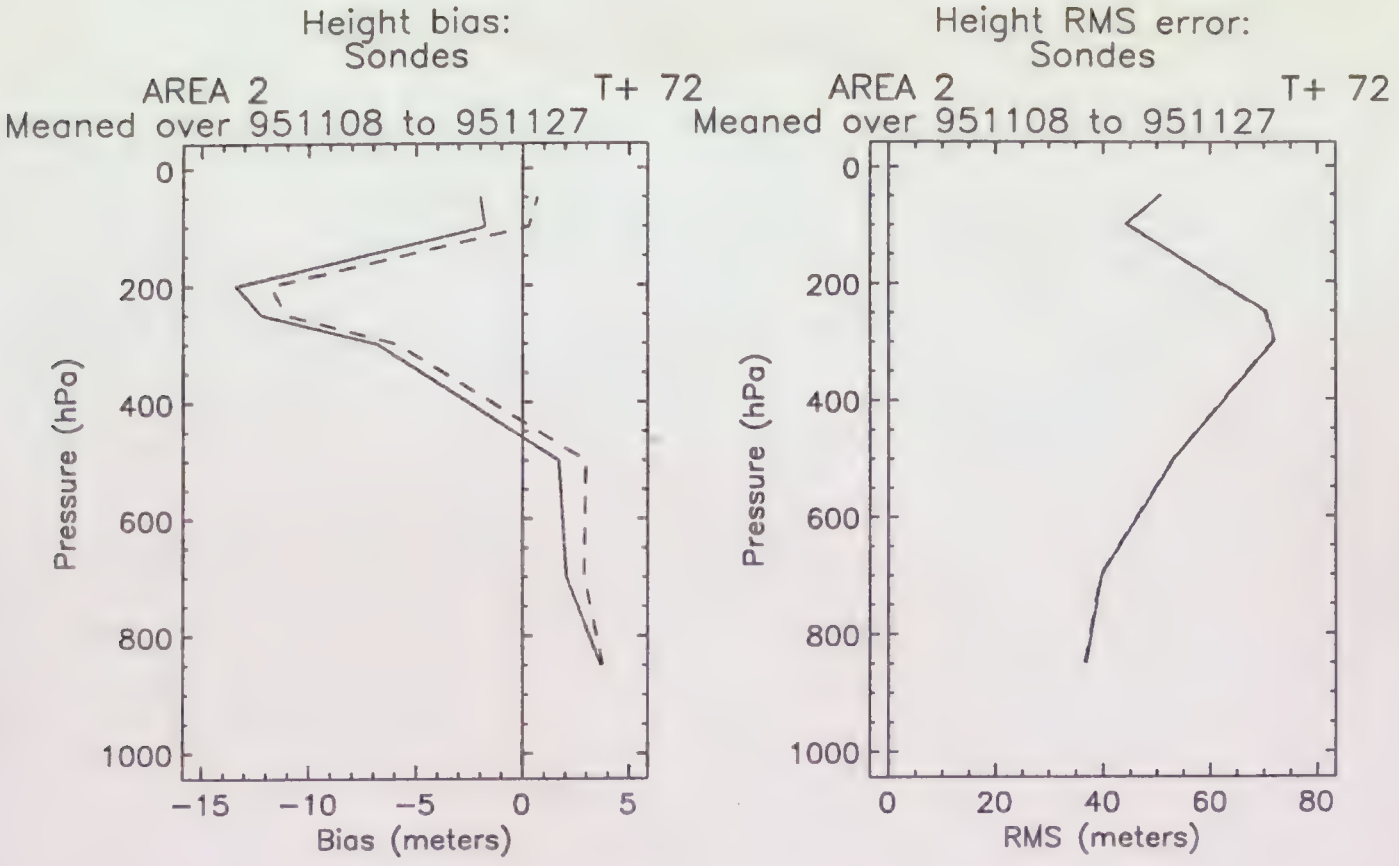

Height bias:
Sondes
AREA 2
T+ 72
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−15
−10
−5
0
5
Bias (meters)
Height RMS error:
Sondes
AREA 2
T+ 72
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
0
20
40
60
80
RMS (meters)

FIGURE 2. 2

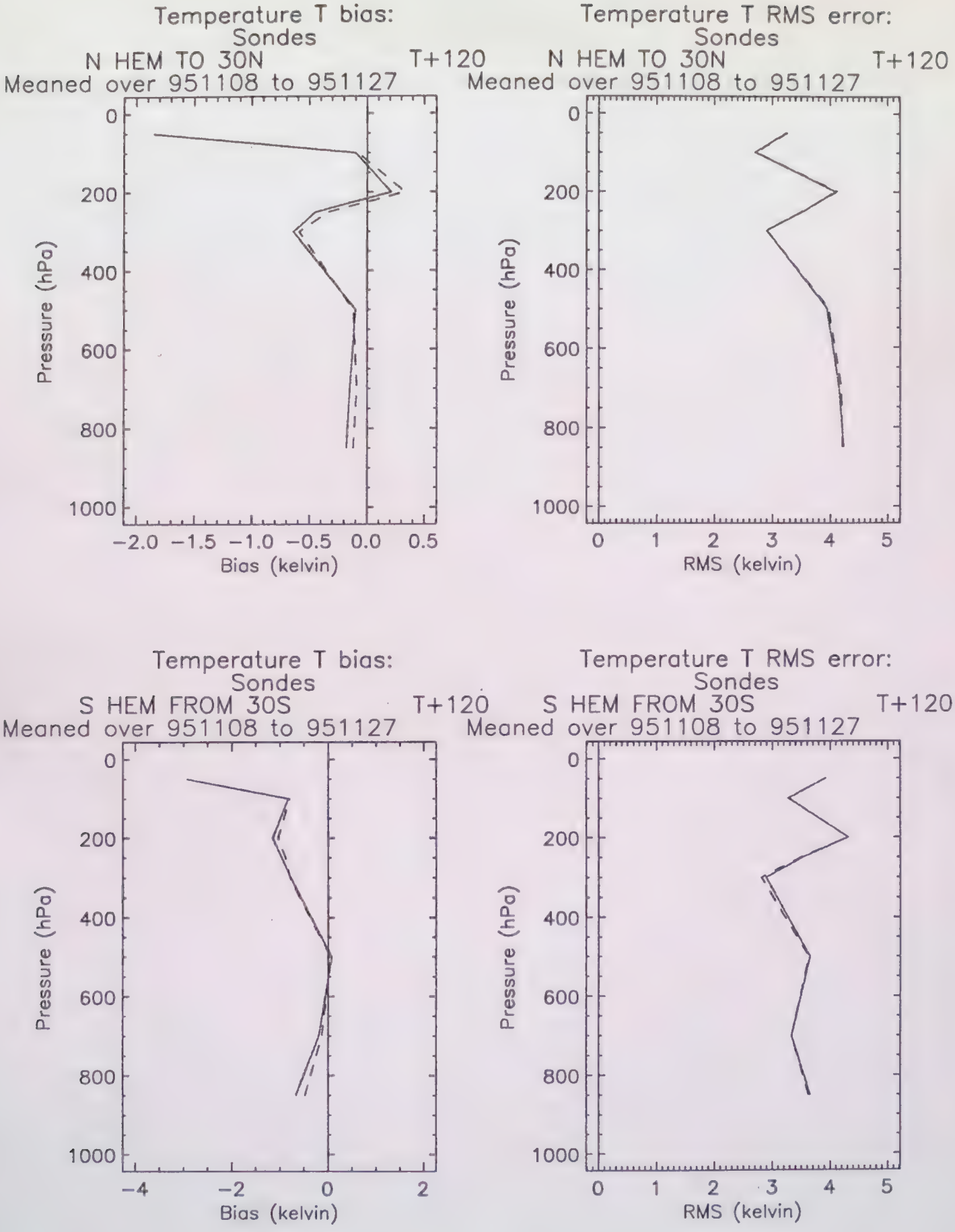

Temperature T bias:
Sondes
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−2.0 −1.5 −1.0 −0.5 0.0 0.5
Bias (kelvin)
Temperature T RMS error:
Sondes
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0 1 2 3 4 5
RMS (kelvin)
Temperature T bias:
Sondes
S HEM FROM 30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
−4 −2 0 2
Bias (kelvin)
Temperature T RMS error:
Sondes
S HEM FROM 30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0 1 2 3 4 5
RMS (kelvin)

FIGURE 2. 3

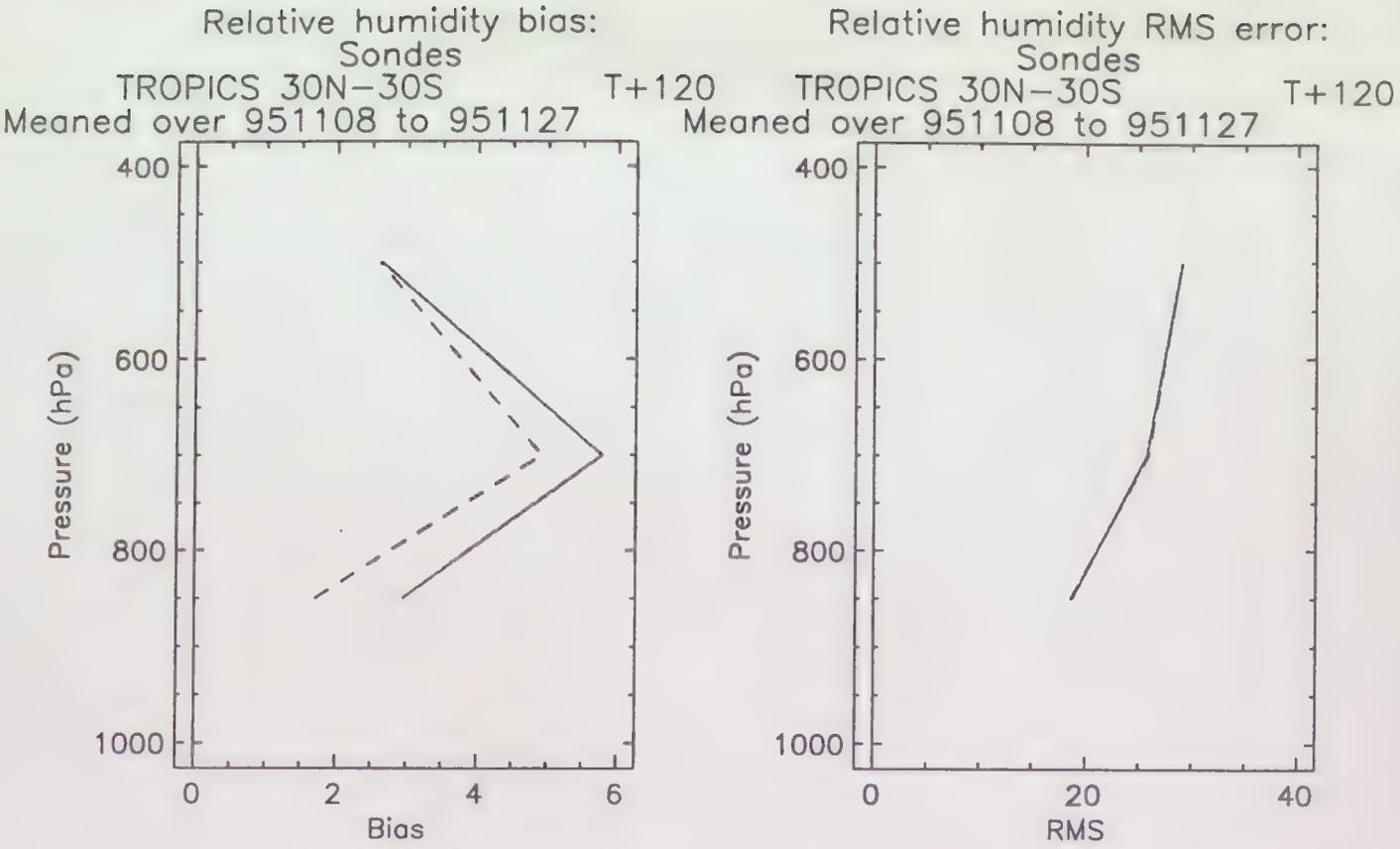

Relative humidity bias:
Sondes
TROPICS 30N–30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
400
600
800
1000
0
2
4
6
Bias
Relative humidity RMS error:
Sondes
TROPICS 30N–30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
400
600
800
1000
0
20
40
RMS

FIGURE 2. 4

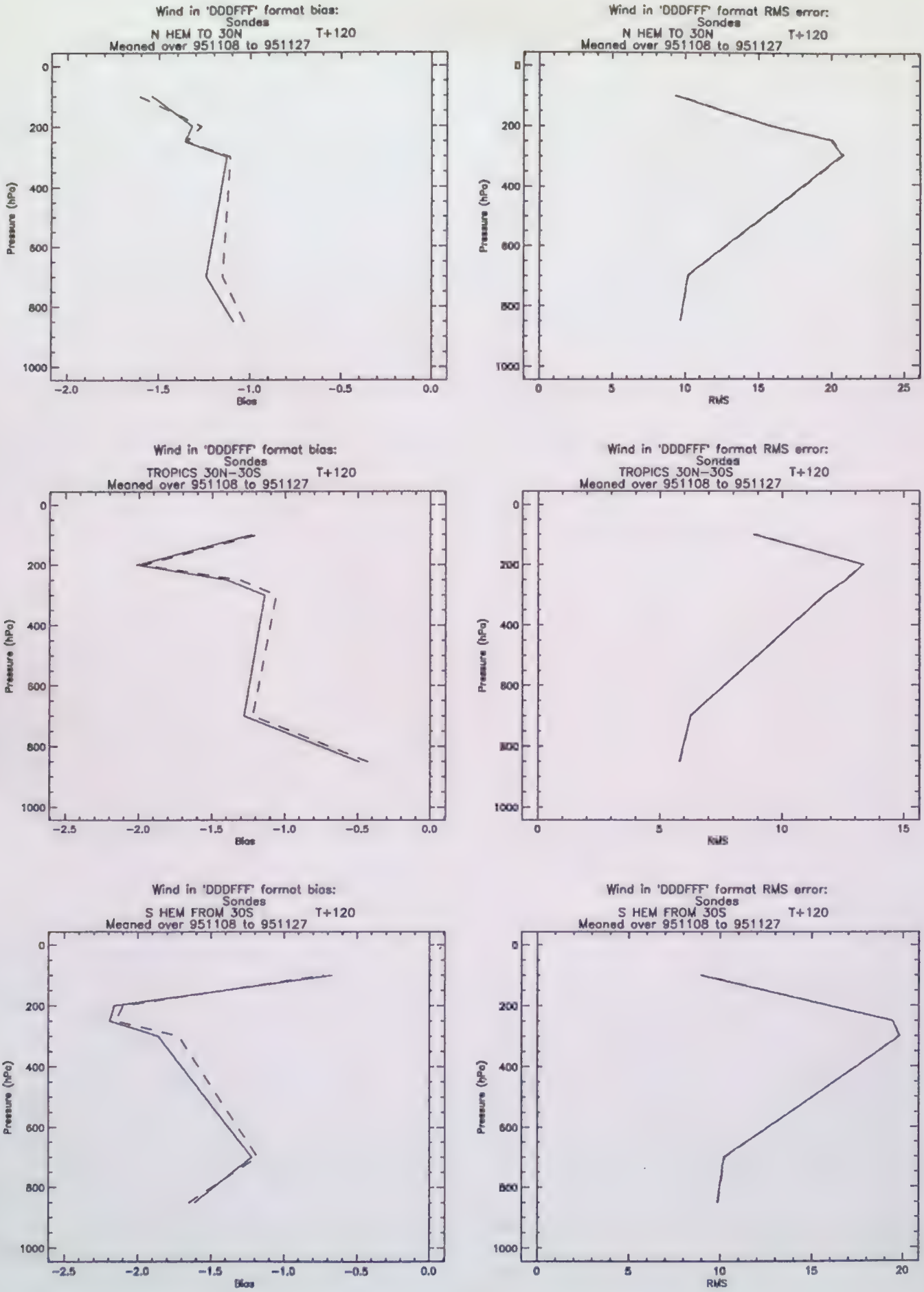

Wind in 'DDDFFF' format bias:
Sondes
N HEM TO 30N T+120
Meaned over 951108 to 951127
Pressure (hPa)
Bias
Wind in 'DDDFFF' format RMS error:
Sondes
N HEM TO 30N T+120
Meaned over 951108 to 951127
Pressure (hPa)
RMS
Wind in 'DDDFFF' format bias:
Sondes
TROPICS 30N-30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
Bias
Wind in 'DDDFFF' format RMS error:
Sondes
TROPICS 30N-30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
RMS
Wind in 'DDDFFF' format bias:
Sondes
S HEM FROM 30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
Bias
Wind in 'DDDFFF' format RMS error:
Sondes
S HEM FROM 30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
RMS

FIGURE 2. 5

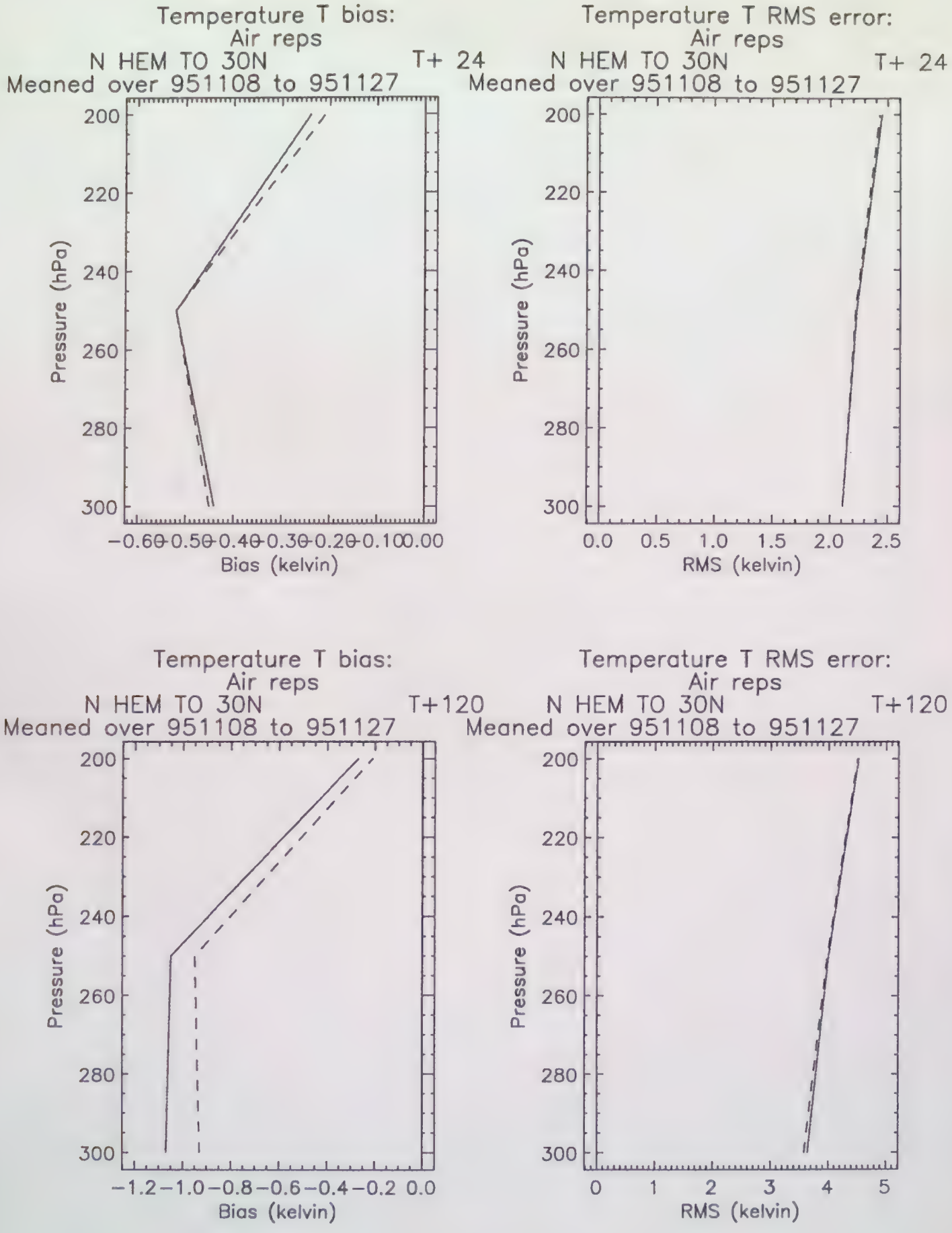

Temperature T bias:
Air reps
N HEM TO 30N
T+ 24
Meaned over 951108 to 951127
Pressure (hPa)
200
220
240
260
280
300
−0.60 −0.50 −0.40 −0.30 −0.20 −0.10 0.00
Bias (kelvin)
Temperature T RMS error:
Air reps
N HEM TO 30N
T+ 24
Meaned over 951108 to 951127
Pressure (hPa)
0.0 0.5 1.0 1.5 2.0 2.5
RMS (kelvin)
Temperature T bias:
Air reps
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
−1.2 −1.0 −0.8 −0.6 −0.4 −0.2 0.0
Bias (kelvin)
Temperature T RMS error:
Air reps
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0 1 2 3 4 5
RMS (kelvin)

FIGURE 2. 6

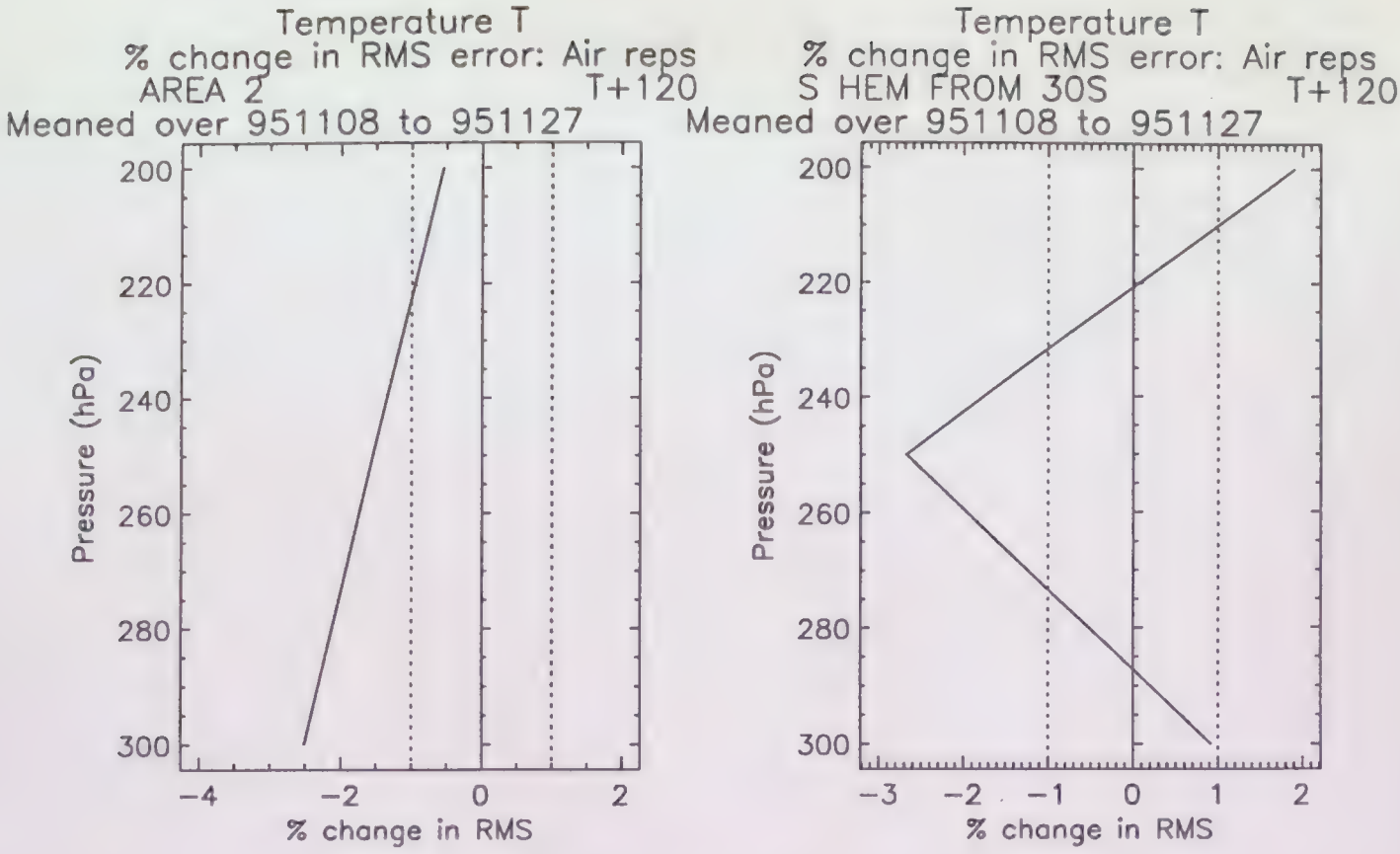

Temperature T
% change in RMS error: Air reps
AREA 2
T+120
Meaned over 951108 to 951127
Pressure (hPa)
200
220
240
260
280
300
−4
−2
0
2
% change in RMS
Temperature T
% change in RMS error: Air reps
S HEM FROM 30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
200
220
240
260
280
300
−3
−2
−1
0
1
2
% change in RMS

FIGURE 2. 7

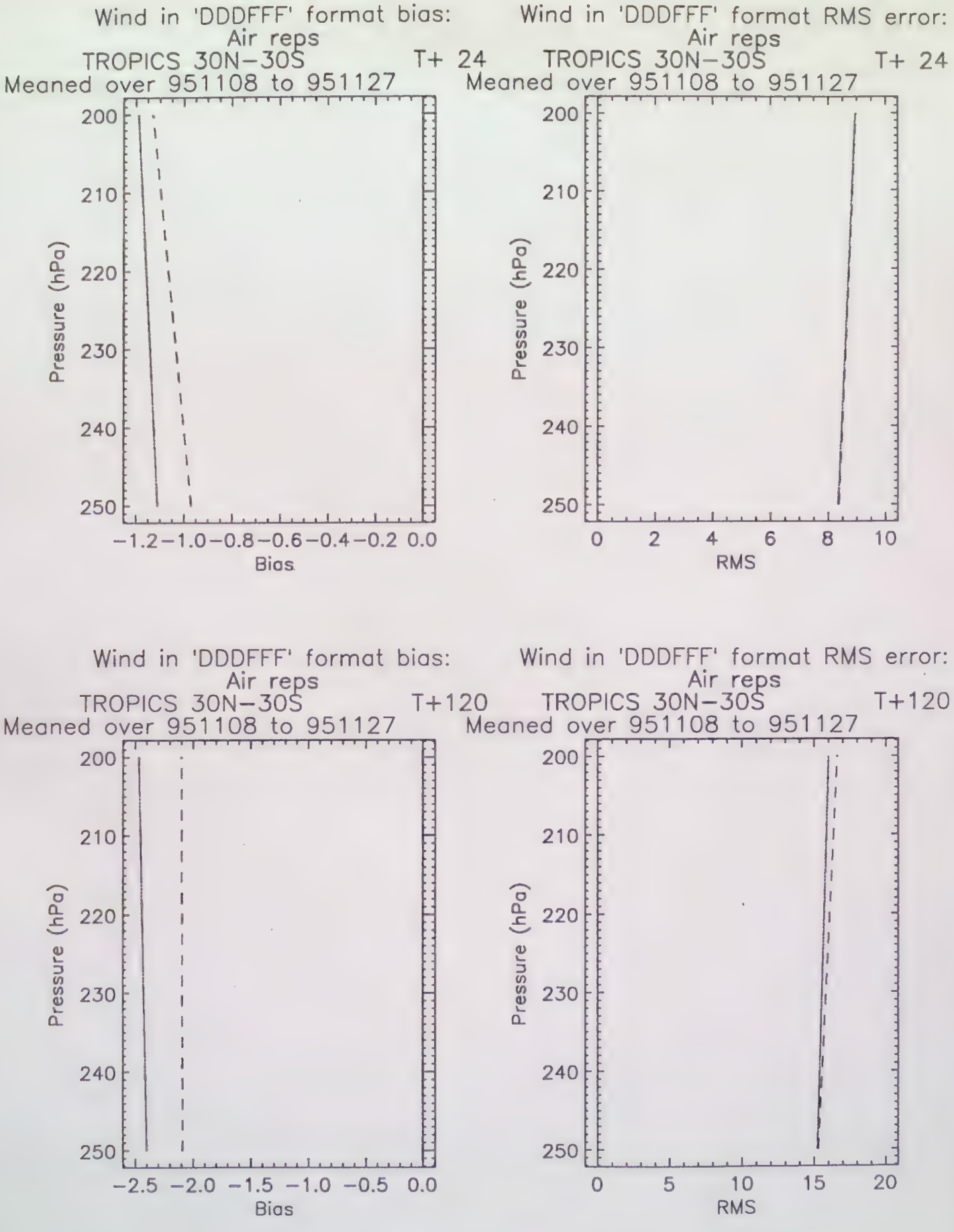

Wind in 'DDDFFF' format bias:
Air reps
TROPICS 30N–30S T+ 24
Meaned over 951108 to 951127
Pressure (hPa)
200
210
220
230
240
250
–1.2 –1.0 –0.8 –0.6 –0.4 –0.2 0.0
Bias
Wind in 'DDDFFF' format RMS error:
Air reps
TROPICS 30N–30S T+ 24
Meaned over 951108 to 951127
Pressure (hPa)
200
210
220
230
240
250
0 2 4 6 8 10
RMS
Wind in 'DDDFFF' format bias:
Air reps
TROPICS 30N–30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
200
210
220
230
240
250
–2.5 –2.0 –1.5 –1.0 –0.5 0.0
Bias
Wind in 'DDDFFF' format RMS error:
Air reps
TROPICS 30N–30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
200
210
220
230
240
250
0 5 10 15 20
RMS

FIGURE 2. 8

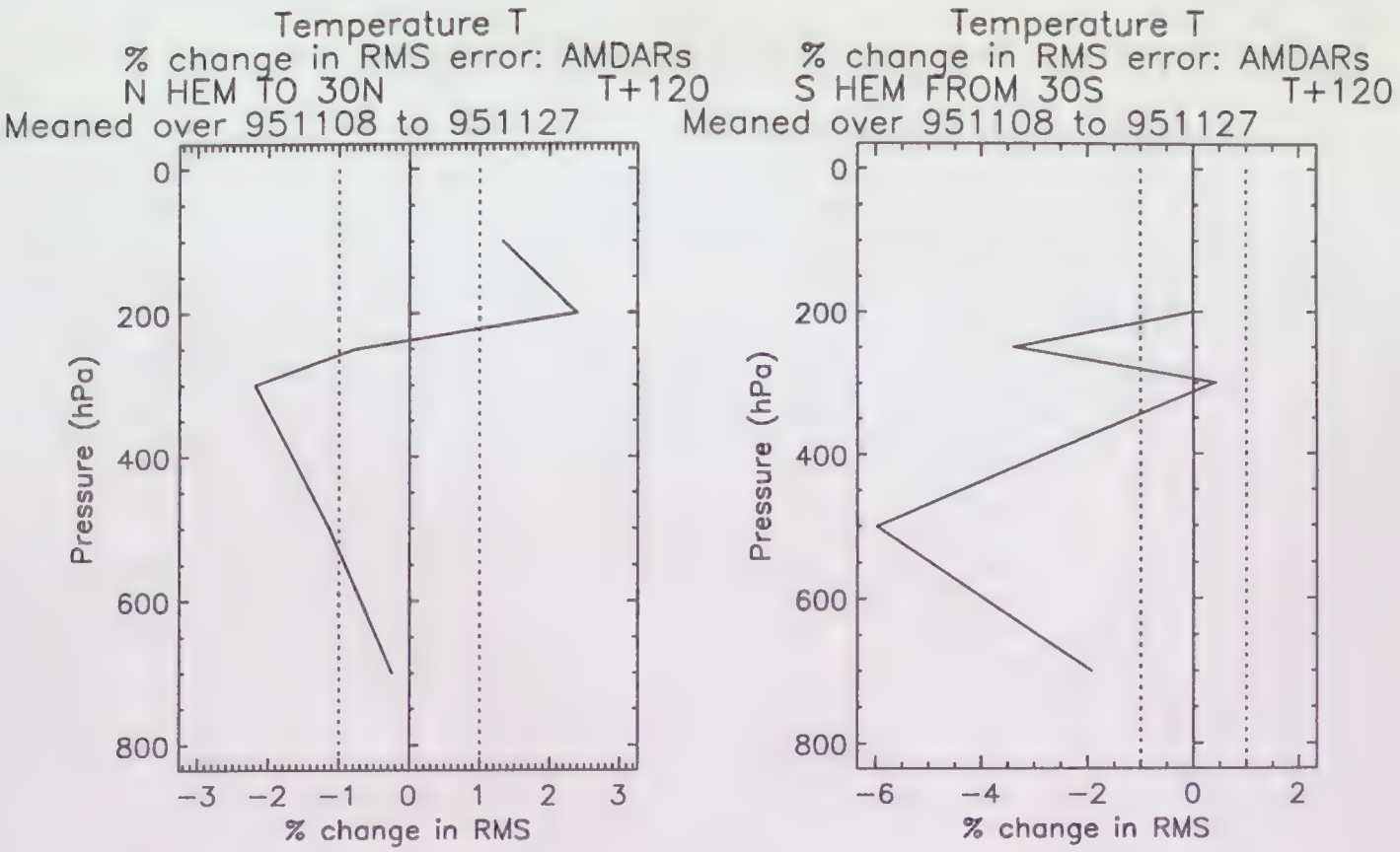

Temperature T
% change in RMS error: AMDARs
N HEM TO 30N T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
−3 −2 −1 0 1 2 3
% change in RMS
Temperature T
% change in RMS error: AMDARs
S HEM FROM 30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
−6 −4 −2 0 2
% change in RMS

FIGURE 2. 9

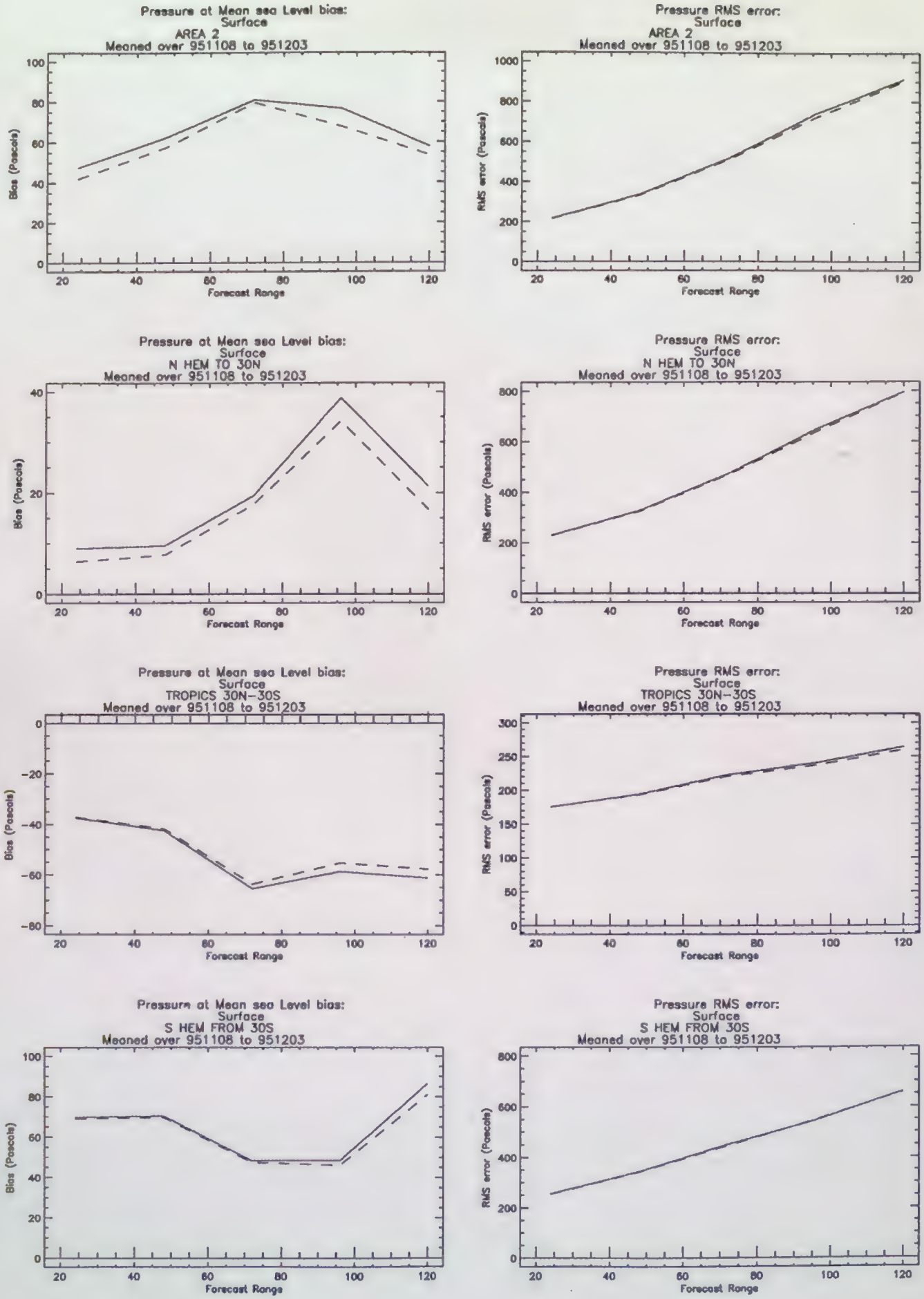

Pressure at Mean sea Level bias:
Surface
AREA 2
Meaned over 951108 to 951203
Bias (Pascals)
Forecast Range
Pressure RMS error:
Surface
AREA 2
Meaned over 951108 to 951203
RMS error (Pascals)
Forecast Range
Pressure at Mean sea Level bias:
Surface
N HEM TO 30N
Meaned over 951108 to 951203
Bias (Pascals)
Forecast Range
Pressure RMS error:
Surface
N HEM TO 30N
Meaned over 951108 to 951203
RMS error (Pascals)
Forecast Range
Pressure at Mean sea Level bias:
Surface
TROPICS 30N-30S
Meaned over 951108 to 951203
Bias (Pascals)
Forecast Range
Pressure RMS error:
Surface
TROPICS 30N-30S
Meaned over 951108 to 951203
RMS error (Pascals)
Forecast Range
Pressure at Mean sea Level bias:
Surface
S HEM FROM 30S
Meaned over 951108 to 951203
Bias (Pascals)
Forecast Range
Pressure RMS error:
Surface
S HEM FROM 30S
Meaned over 951108 to 951203
RMS error (Pascals)
Forecast Range

FIGURE 2. 10

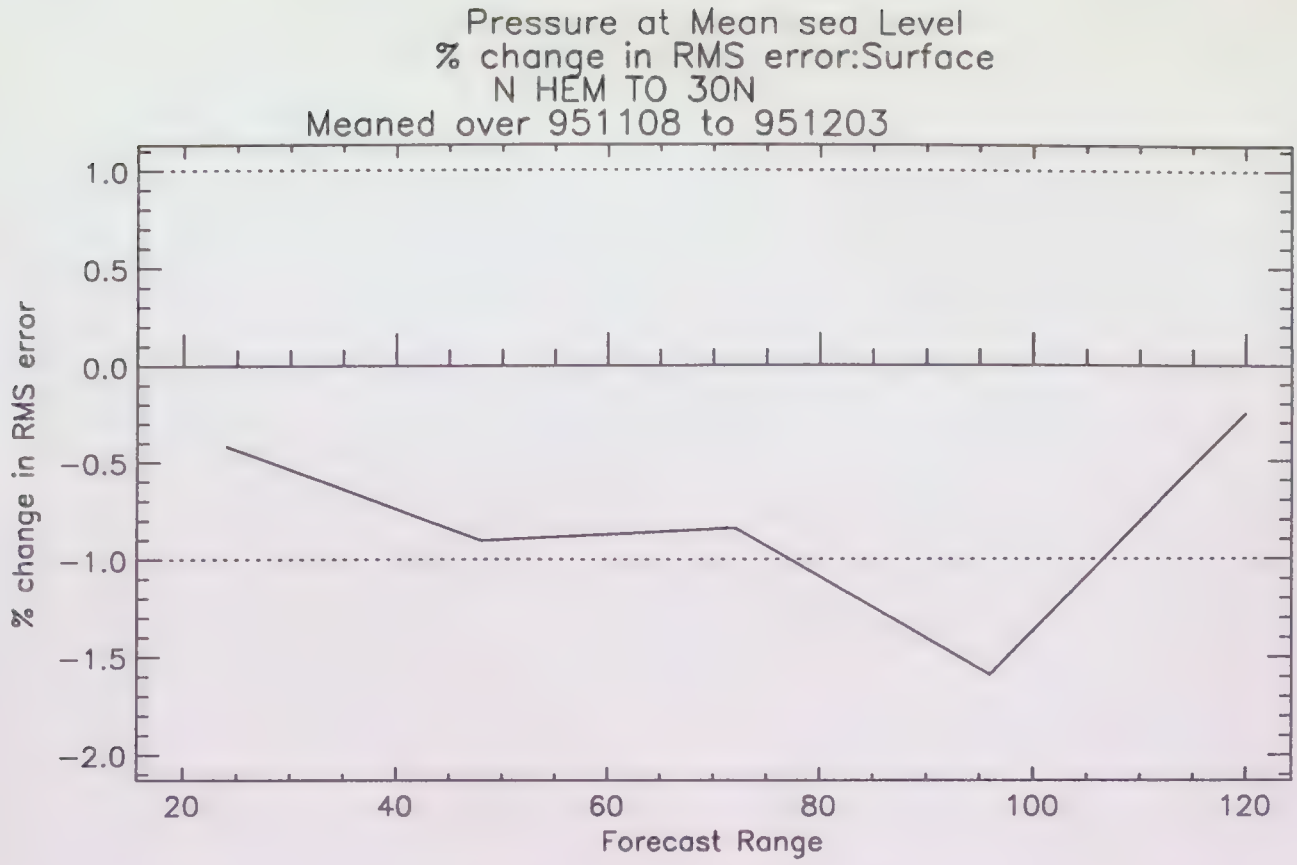

Pressure at Mean sea Level
% change in RMS error:Surface
N HEM TO 30N
Meaned over 951108 to 951203
% change in RMS error
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
20
40
60
80
100
120
Forecast Range

FIGURE 2. 11

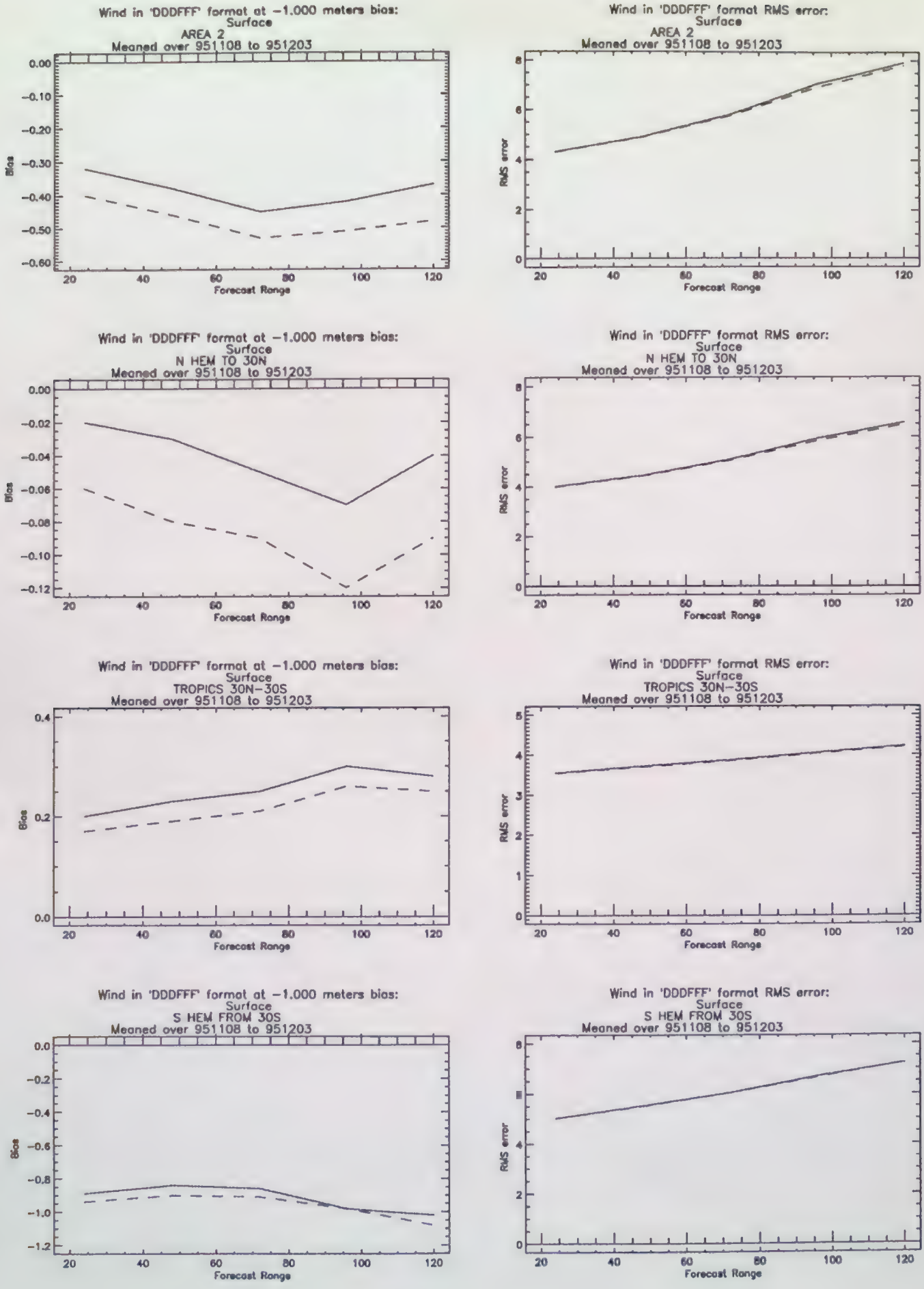

Wind in 'DDDFFF' format at −1.000 meters bias:
Surface
AREA 2
Meaned over 951108 to 951203
Bias
Forecast Range
Wind in 'DDDFFF' format RMS error:
Surface
AREA 2
Meaned over 951108 to 951203
RMS error
Forecast Range
Wind in 'DDDFFF' format at −1.000 meters bias:
Surface
N HEM TO 30N
Meaned over 951108 to 951203
Bias
Forecast Range
Wind in 'DDDFFF' format RMS error:
Surface
N HEM TO 30N
Meaned over 951108 to 951203
RMS error
Forecast Range
Wind in 'DDDFFF' format at −1.000 meters bias:
Surface
TROPICS 30N−30S
Meaned over 951108 to 951203
Bias
Forecast Range
Wind in 'DDDFFF' format RMS error:
Surface
TROPICS 30N−30S
Meaned over 951108 to 951203
RMS error
Forecast Range
Wind in 'DDDFFF' format at −1.000 meters bias:
Surface
S HEM FROM 30S
Meaned over 951108 to 951203
Bias
Forecast Range
Wind in 'DDDFFF' format RMS error:
Surface
S HEM FROM 30S
Meaned over 951108 to 951203
RMS error
Forecast Range

FIGURE 2. 12

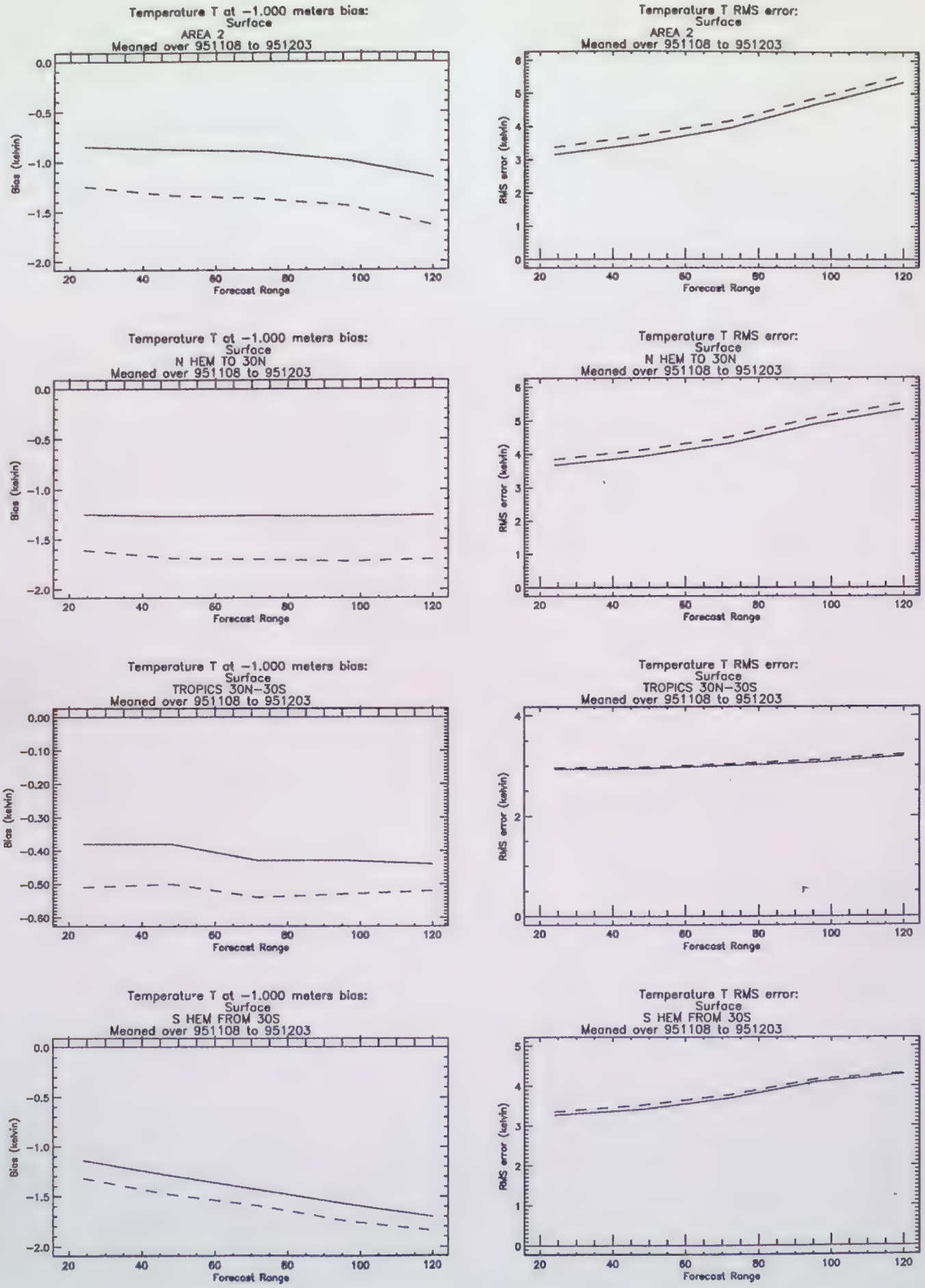

Temperature T at −1.000 meters bias:
Surface
AREA 2
Meaned over 951108 to 951203
Bias (kelvin)
Forecast Range
Temperature T RMS error:
Surface
AREA 2
Meaned over 951108 to 951203
RMS error (kelvin)
Forecast Range
Temperature T at −1.000 meters bias:
Surface
N HEM TO 30N
Meaned over 951108 to 951203
Bias (kelvin)
Forecast Range
Temperature T RMS error:
Surface
N HEM TO 30N
Meaned over 951108 to 951203
RMS error (kelvin)
Forecast Range
Temperature T at −1.000 meters bias:
Surface
TROPICS 30N−30S
Meaned over 951108 to 951203
Bias (kelvin)
Forecast Range
Temperature T RMS error:
Surface
TROPICS 30N−30S
Meaned over 951108 to 951203
RMS error (kelvin)
Forecast Range
Temperature T at −1.000 meters bias:
Surface
S HEM FROM 30S
Meaned over 951108 to 951203
Bias (kelvin)
Forecast Range
Temperature T RMS error:
Surface
S HEM FROM 30S
Meaned over 951108 to 951203
RMS error (kelvin)
Forecast Range

FIGURE 2. 13

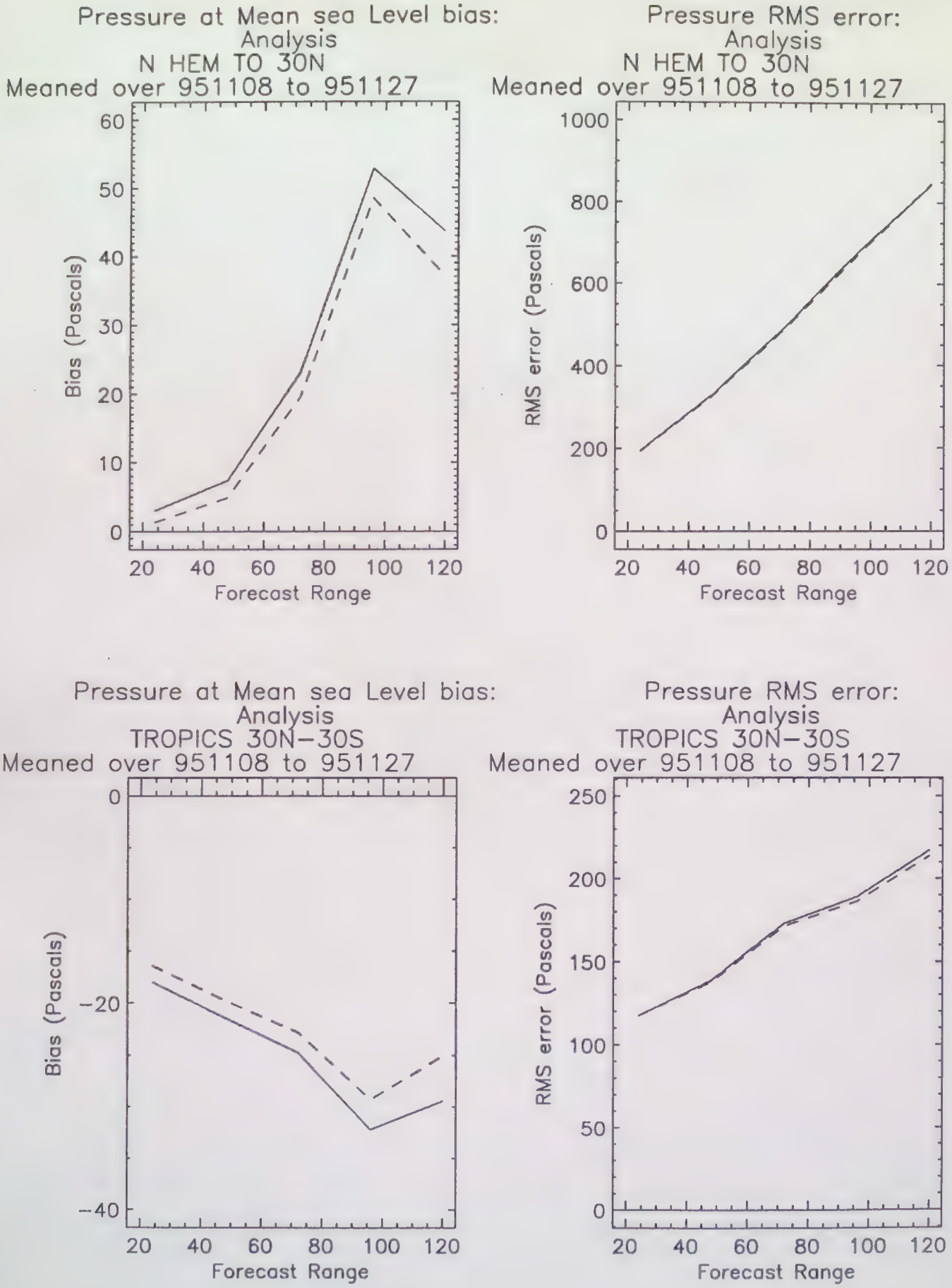

Pressure at Mean sea Level bias:
Analysis
N HEM TO 30N
Meaned over 951108 to 951127
Bias (Pascals)
Forecast Range
Pressure RMS error:
Analysis
N HEM TO 30N
Meaned over 951108 to 951127
RMS error (Pascals)
Forecast Range
Pressure at Mean sea Level bias:
Analysis
TROPICS 30N–30S
Meaned over 951108 to 951127
Bias (Pascals)
Forecast Range
Pressure RMS error:
Analysis
TROPICS 30N–30S
Meaned over 951108 to 951127
RMS error (Pascals)
Forecast Range

FIGURE 2. 14

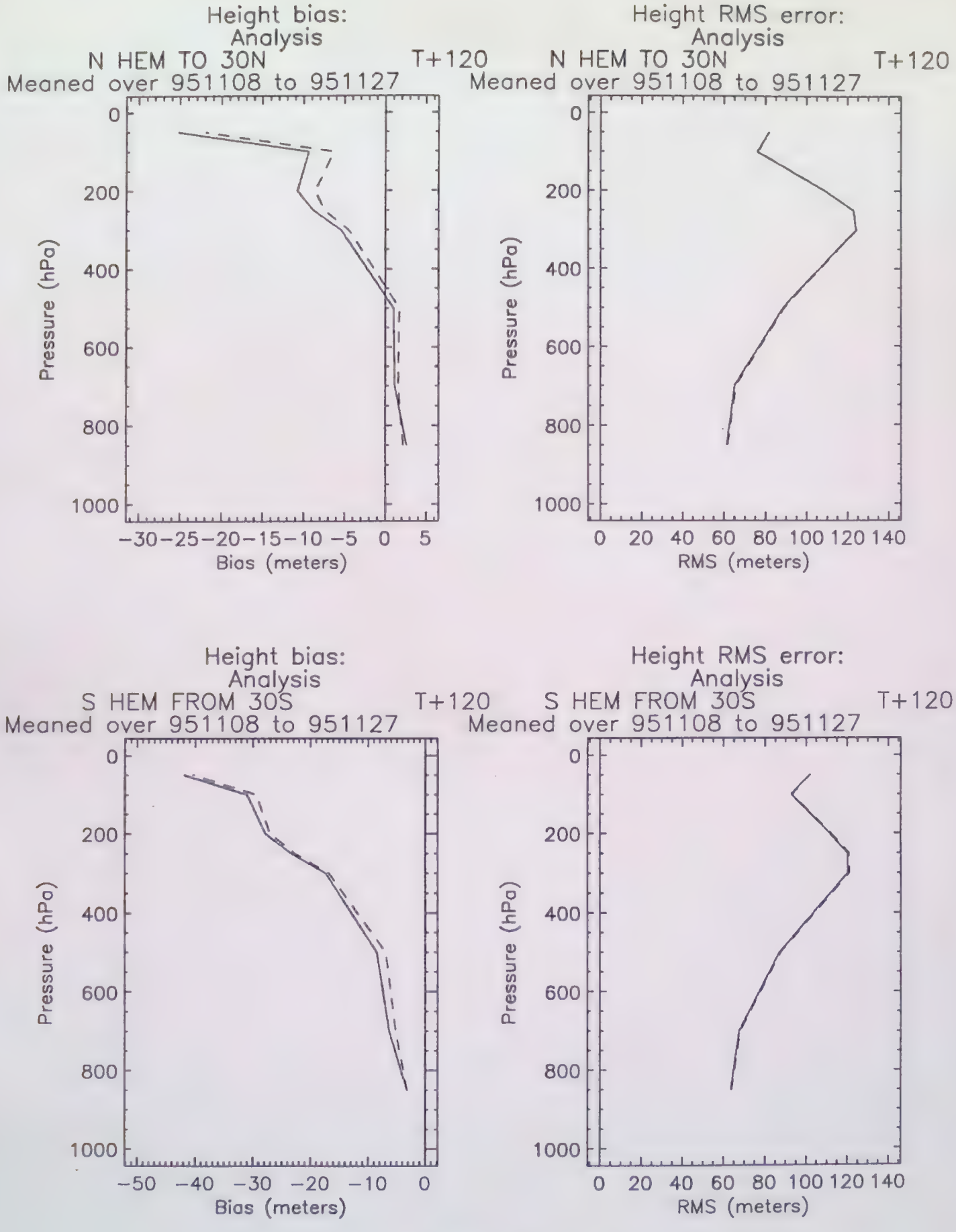

Height bias:
Analysis
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−30 −25 −20 −15 −10 −5 0 5
Bias (meters)
Height RMS error:
Analysis
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0 20 40 60 80 100 120 140
RMS (meters)
Height bias:
Analysis
S HEM FROM 30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
−50 −40 −30 −20 −10 0
Bias (meters)
Height RMS error:
Analysis
S HEM FROM 30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0 20 40 60 80 100 120 140
RMS (meters)

FIGURE 2. 15

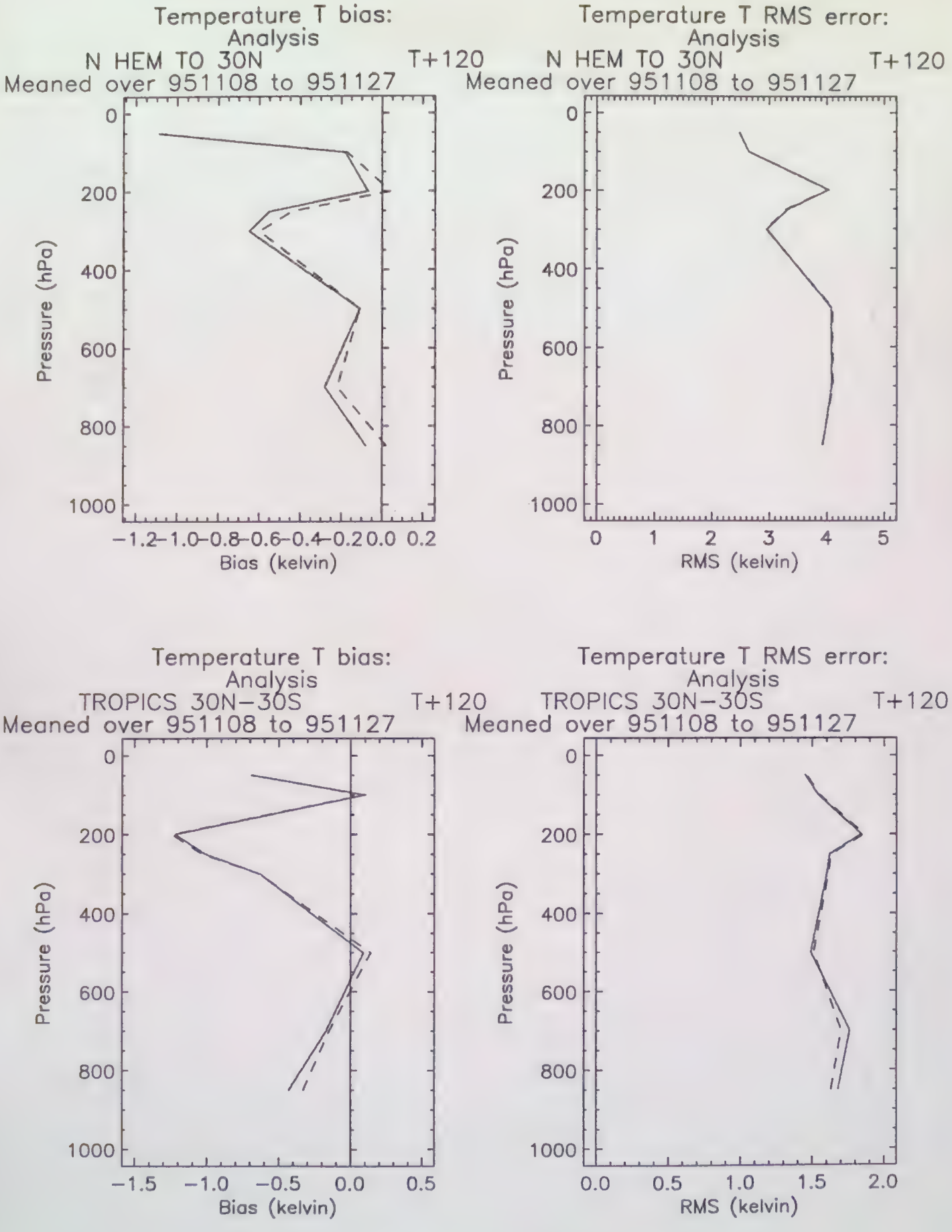
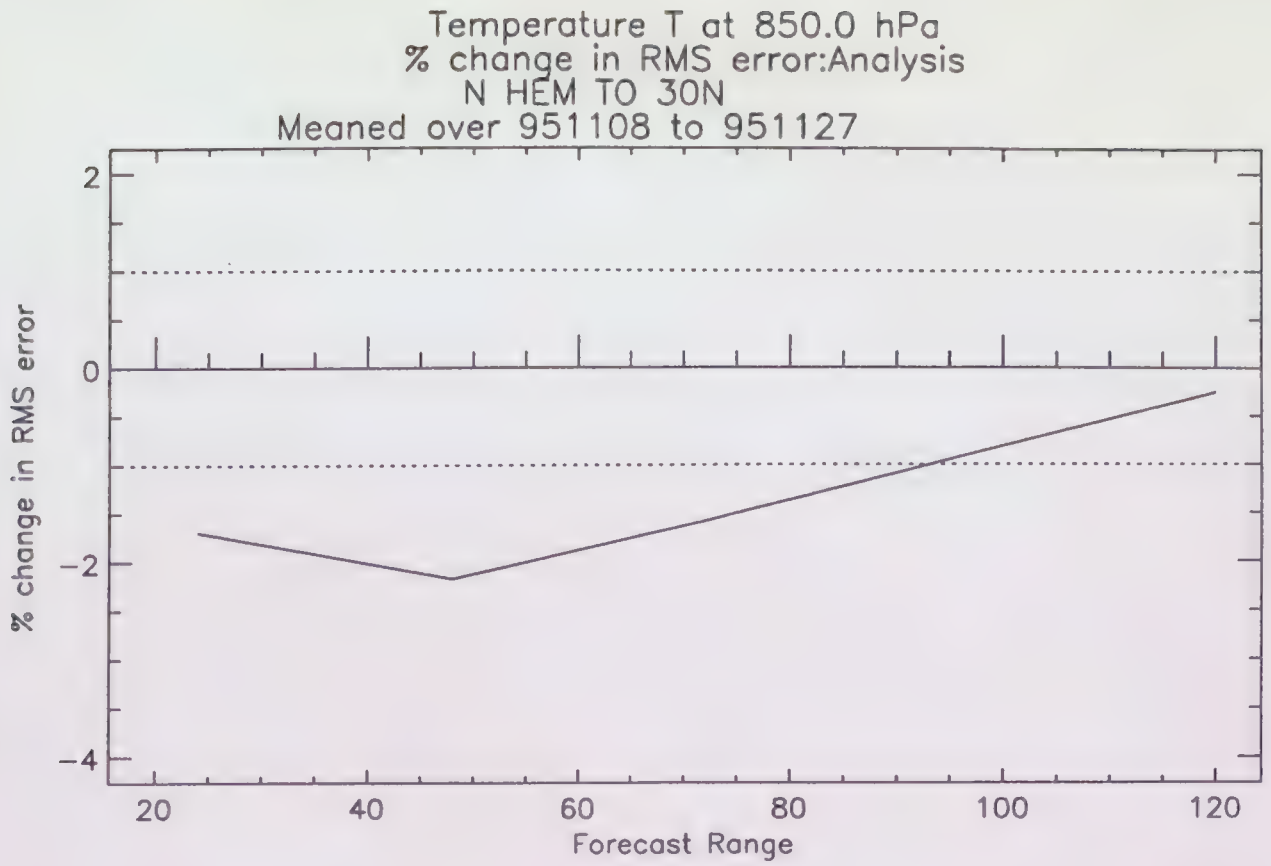

Temperature T bias:
Analysis
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−1.2 −1.0 −0.8 −0.6 −0.4 −0.2 0.0 0.2
Bias (kelvin)
Temperature T RMS error:
Analysis
N HEM TO 30N
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
0 1 2 3 4 5
RMS (kelvin)
Temperature T bias:
Analysis
TROPICS 30N−30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−1.5 −1.0 −0.5 0.0 0.5
Bias (kelvin)
Temperature T RMS error:
Analysis
TROPICS 30N−30S
T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
0.0 0.5 1.0 1.5 2.0
RMS (kelvin)

FIGURE 2. 16


Temperature T at 850.0 hPa
% change in RMS error:Analysis
N HEM TO 30N
Meaned over 951108 to 951127
% change in RMS error
2
0
−2
−4
20
40
60
80
100
120
Forecast Range

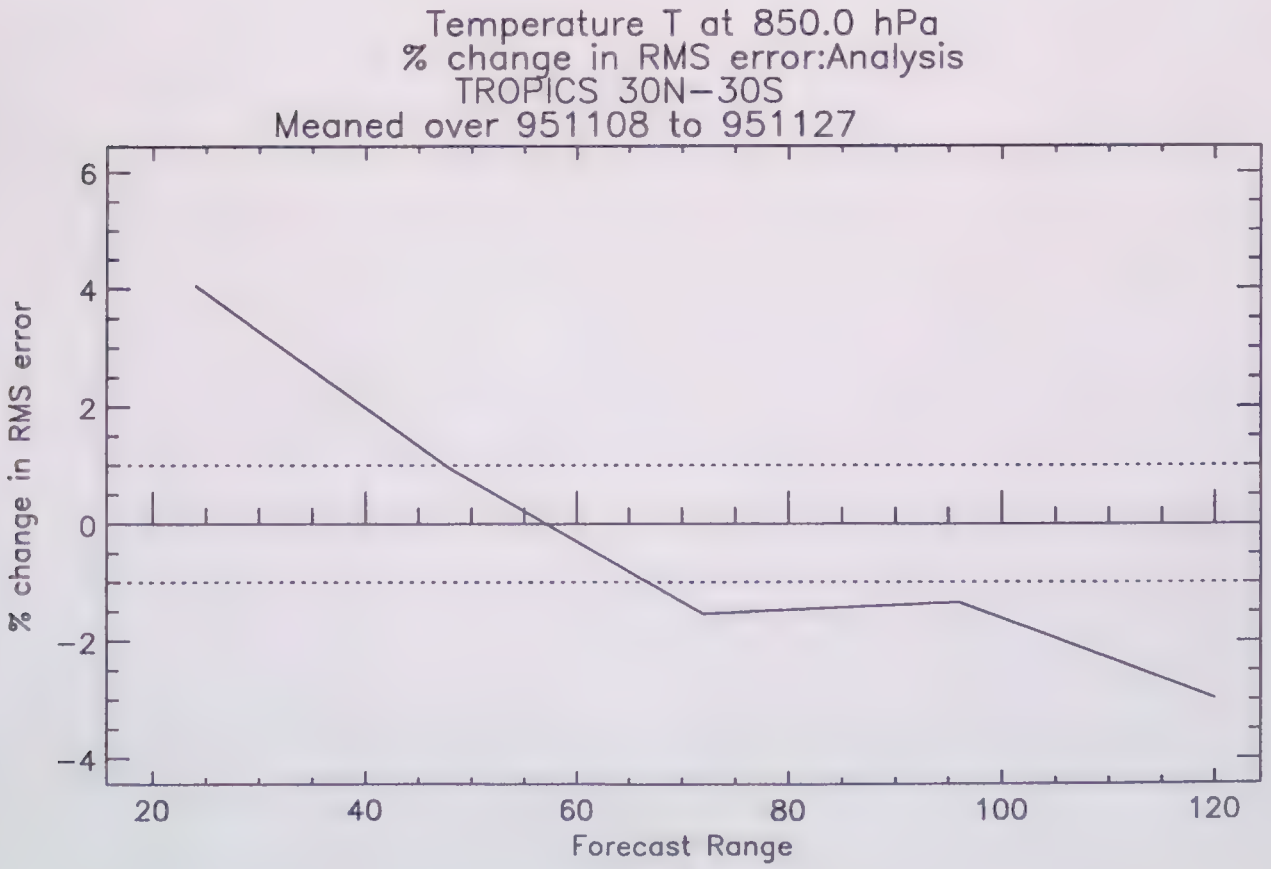

Temperature T at 850.0 hPa
% change in RMS error:Analysis
TROPICS 30N−30S
Meaned over 951108 to 951127
% change in RMS error
6
4
2
0
−2
−4
20
40
60
80
100
120
Forecast Range

FIGURE 2. 17

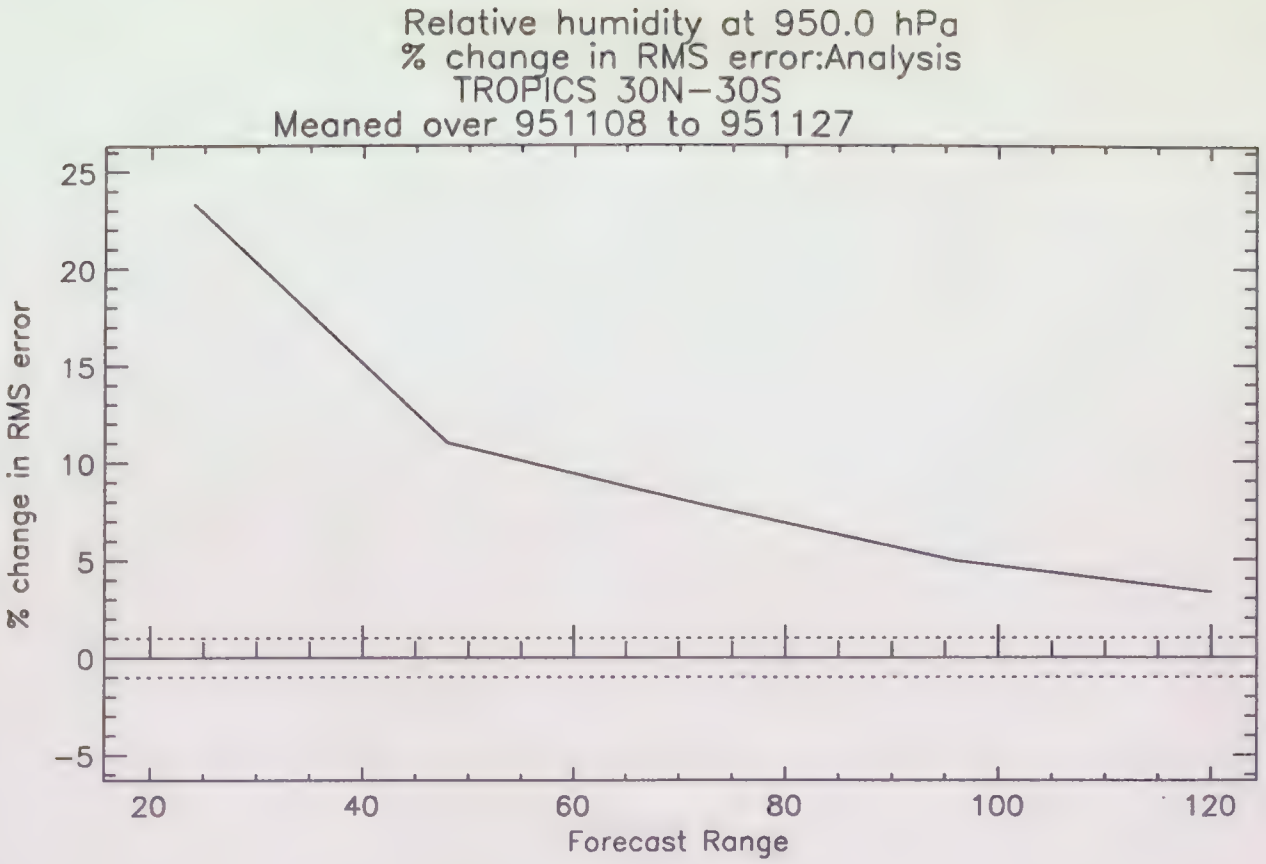

Relative humidity at 950.0 hPa
% change in RMS error:Analysis
TROPICS 30N−30S
Meaned over 951108 to 951127
% change in RMS error
25
20
15
10
5
0
−5
20
40
60
80
100
120
Forecast Range

FIGURE 2. 18

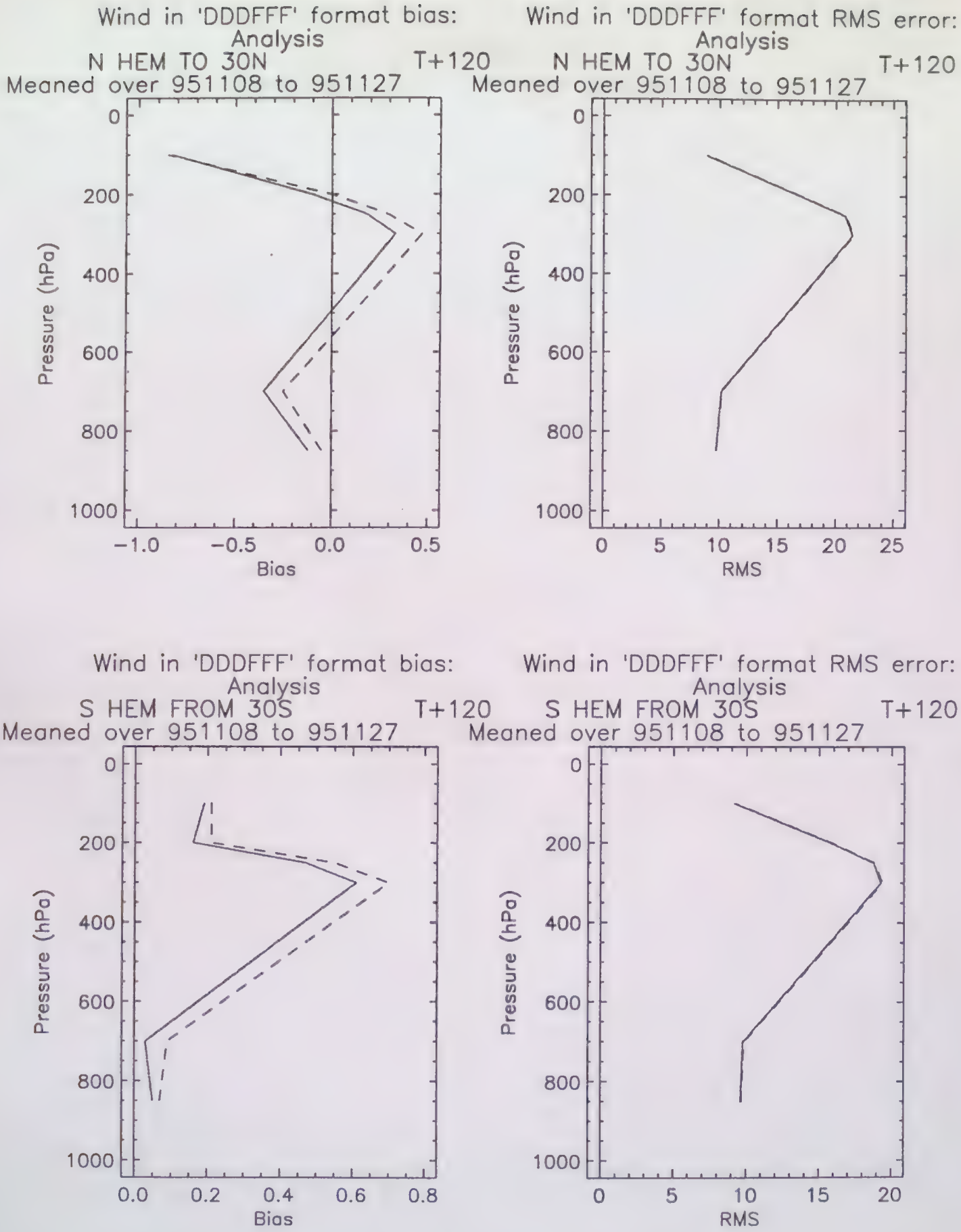

Wind in 'DDDFFF' format bias:
Analysis
N HEM TO 30N T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
−1.0
−0.5
0.0
0.5
Bias
Wind in 'DDDFFF' format RMS error:
Analysis
N HEM TO 30N T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
0
5
10
15
20
25
RMS
Wind in 'DDDFFF' format bias:
Analysis
S HEM FROM 30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
0.0
0.2
0.4
0.6
0.8
Bias
Wind in 'DDDFFF' format RMS error:
Analysis
S HEM FROM 30S T+120
Meaned over 951108 to 951127
Pressure (hPa)
0
200
400
600
800
1000
0
5
10
15
20
RMS

FIGURE 2. 19

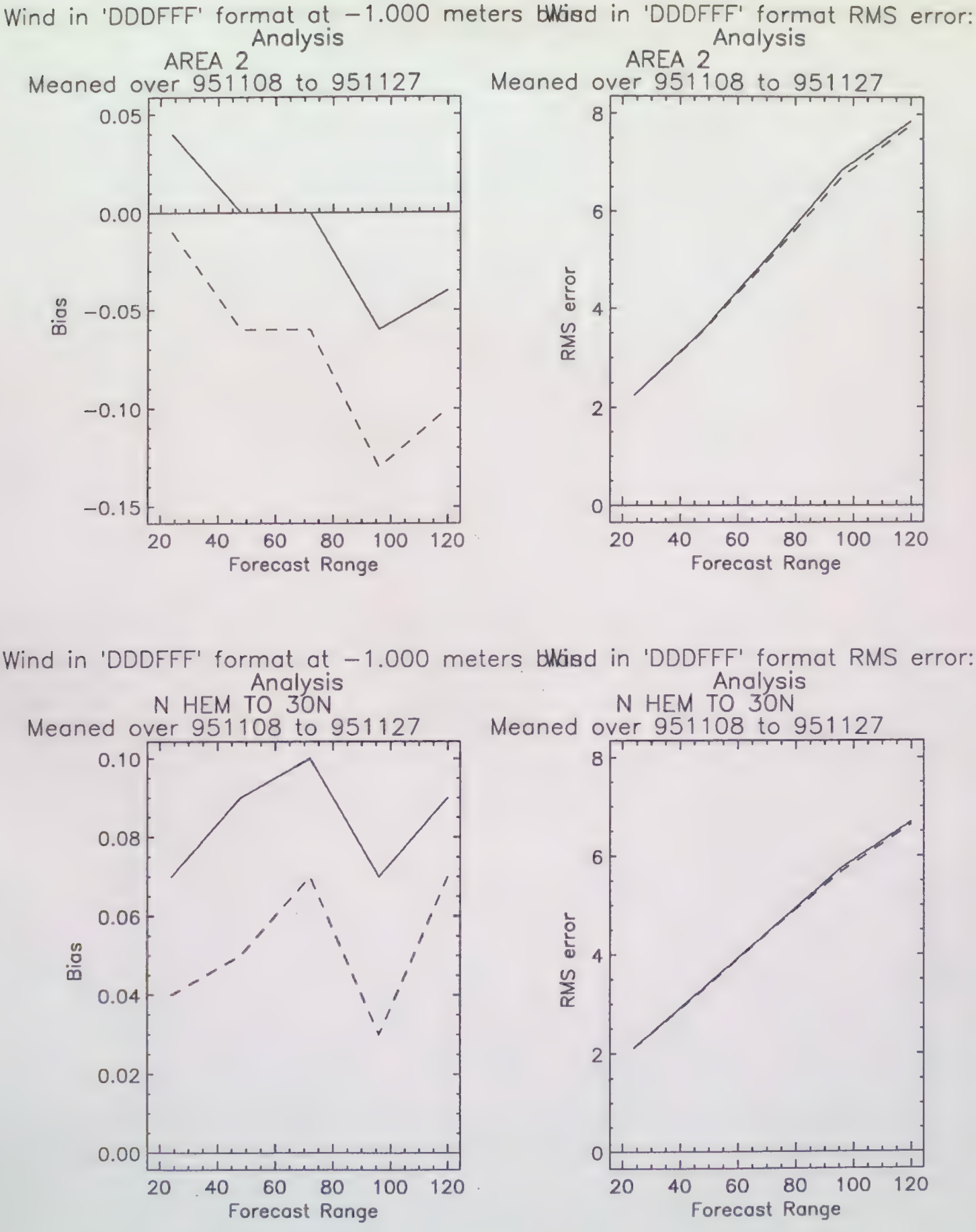

Wind in 'DDDFFF' format at −1.000 meters bias
Analysis
AREA 2
Meaned over 951108 to 951127
Bias
0.05
0.00
−0.05
−0.10
−0.15
20 40 60 80 100 120
Forecast Range
Wind in 'DDDFFF' format RMS error:
Analysis
AREA 2
Meaned over 951108 to 951127
RMS error
8
6
4
2
0
20 40 60 80 100 120
Forecast Range
Wind in 'DDDFFF' format at −1.000 meters bias
Analysis
N HEM TO 30N
Meaned over 951108 to 951127
Bias
0.10
0.08
0.06
0.04
0.02
0.00
20 40 60 80 100 120
Forecast Range
Wind in 'DDDFFF' format RMS error:
Analysis
N HEM TO 30N
Meaned over 951108 to 951127
RMS error
8
6
4
2
0
20 40 60 80 100 120
Forecast Range

FIGURE 2. 20

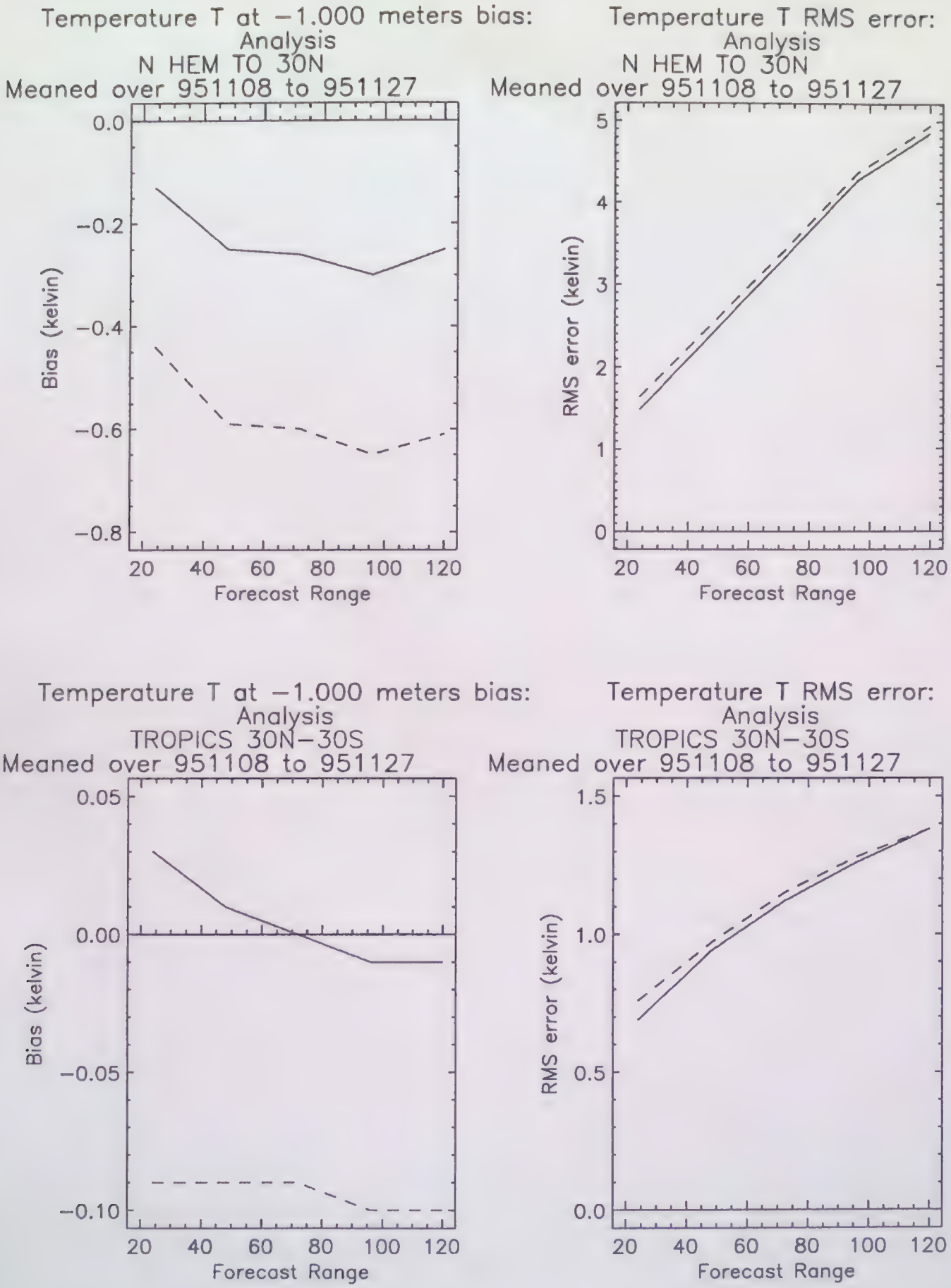

Temperature T at −1.000 meters bias:
Analysis
N HEM TO 30N
Meaned over 951108 to 951127
Bias (kelvin)
0.0
−0.2
−0.4
−0.6
−0.8
20 40 60 80 100 120
Forecast Range
Temperature T RMS error:
Analysis
N HEM TO 30N
Meaned over 951108 to 951127
RMS error (kelvin)
0 1 2 3 4 5
20 40 60 80 100 120
Forecast Range
Temperature T at −1.000 meters bias:
Analysis
TROPICS 30N−30S
Meaned over 951108 to 951127
Bias (kelvin)
0.05
0.00
−0.05
−0.10
20 40 60 80 100 120
Forecast Range
Temperature T RMS error:
Analysis
TROPICS 30N−30S
Meaned over 951108 to 951127
RMS error (kelvin)
0.0 0.5 1.0 1.5
20 40 60 80 100 120
Forecast Range

FIGURE 2. 21

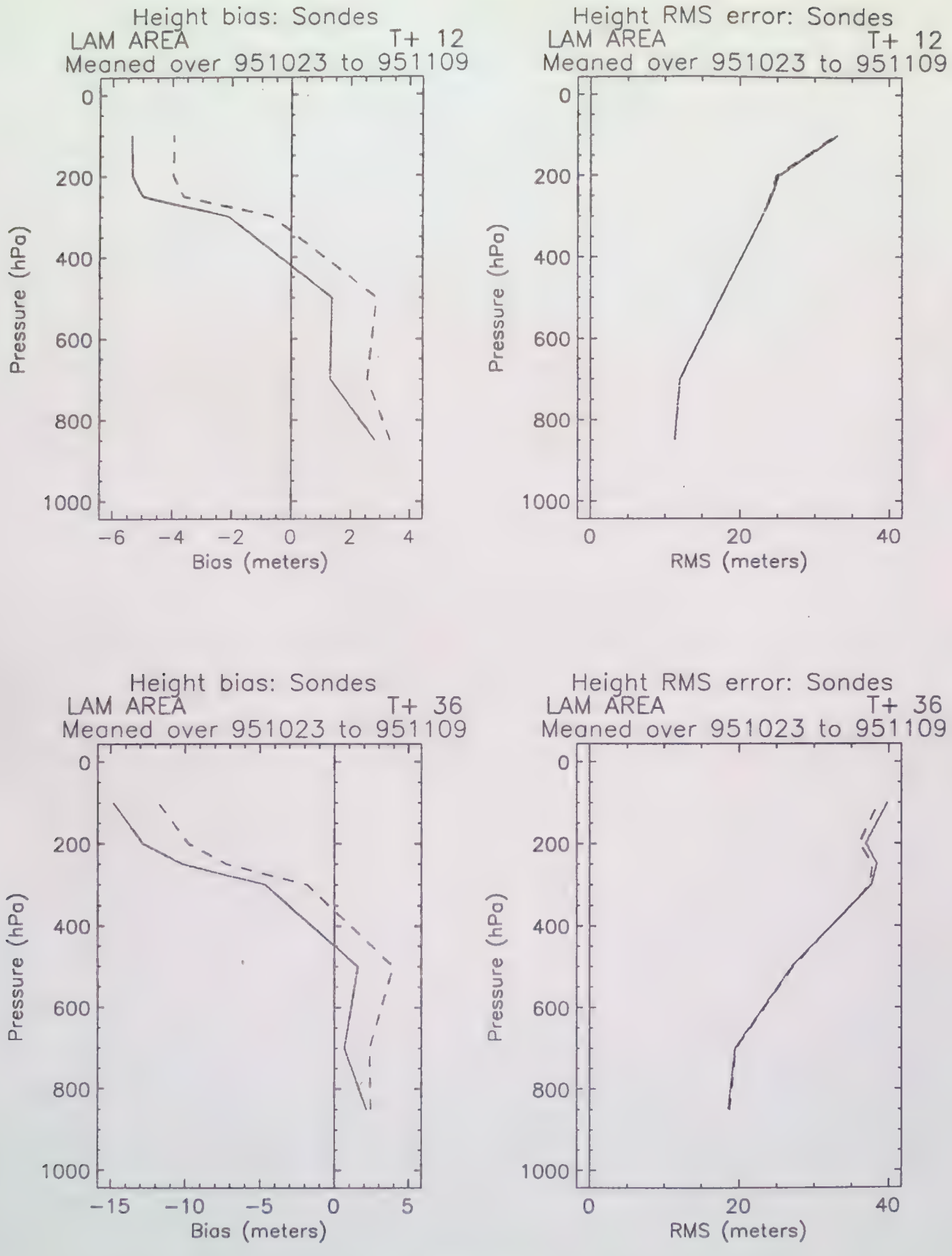

Height bias: Sondes
LAM AREA
T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−6
−4
−2
0
2
4
Bias (meters)
Height RMS error: Sondes
LAM AREA
T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
0
20
40
RMS (meters)
Height bias: Sondes
LAM AREA
T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−15
−10
−5
0
5
Bias (meters)
Height RMS error: Sondes
LAM AREA
T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
0
20
40
RMS (meters)

FIGURE 2. 22

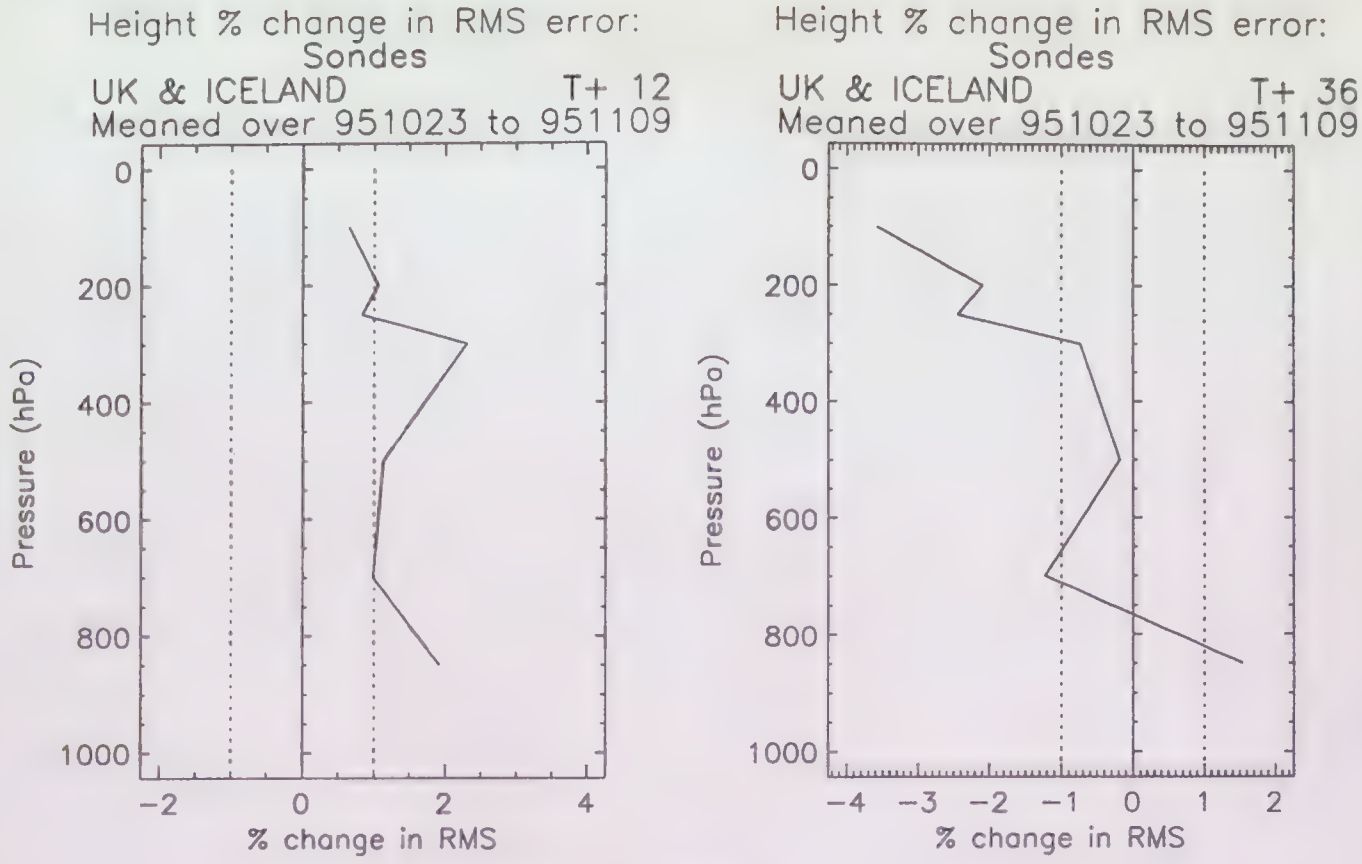

Height % change in RMS error:
Sondes
UK & ICELAND
T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−2
0
2
4
% change in RMS
Height % change in RMS error:
Sondes
UK & ICELAND
T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−4
−3
−2
−1
0
1
2
% change in RMS

FIGURE 2. 23

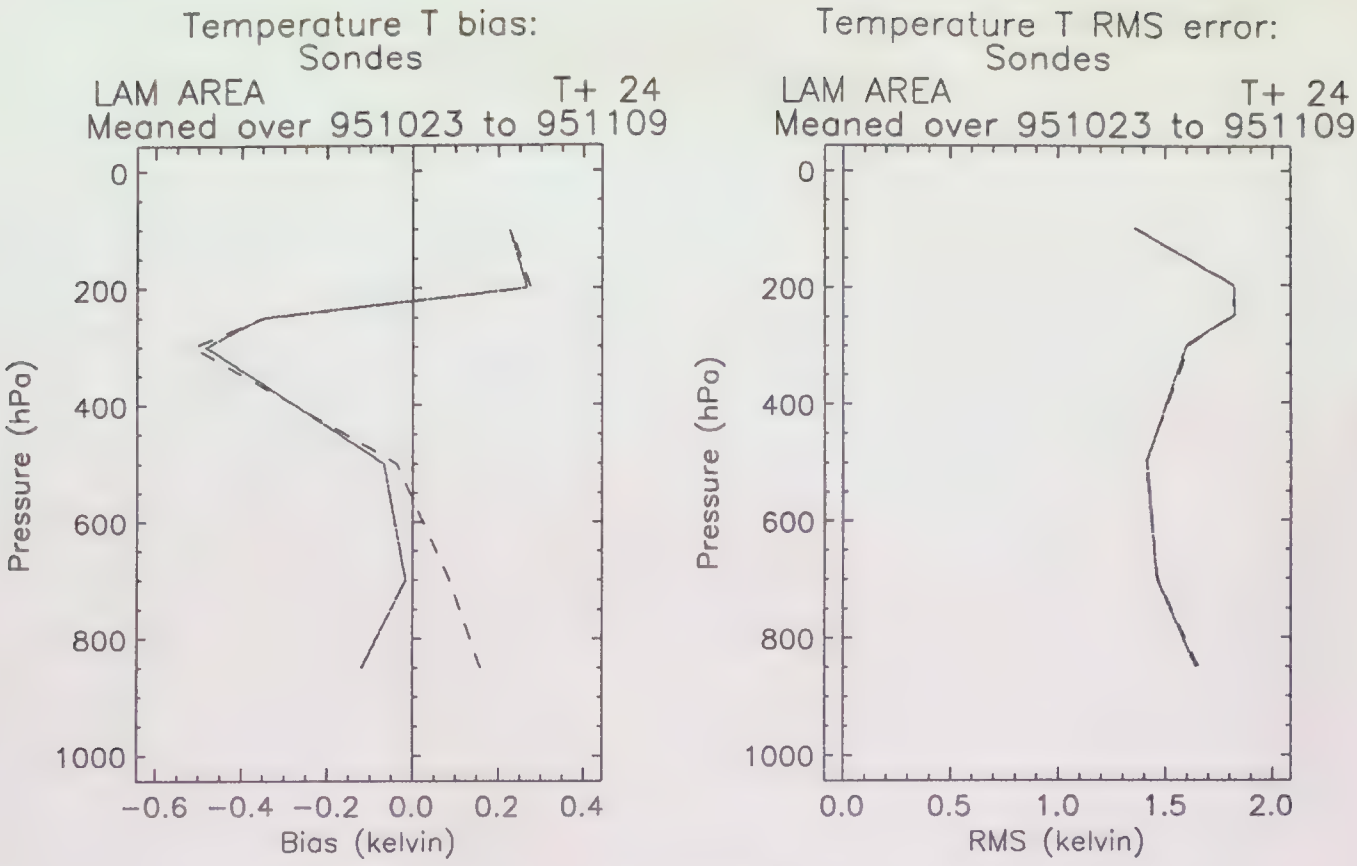

Temperature T bias:
Sondes
LAM AREA
T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−0.6 −0.4 −0.2 0.0 0.2 0.4
Bias (kelvin)
Temperature T RMS error:
Sondes
LAM AREA
T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
0.0 0.5 1.0 1.5 2.0
RMS (kelvin)

FIGURE 2. 24

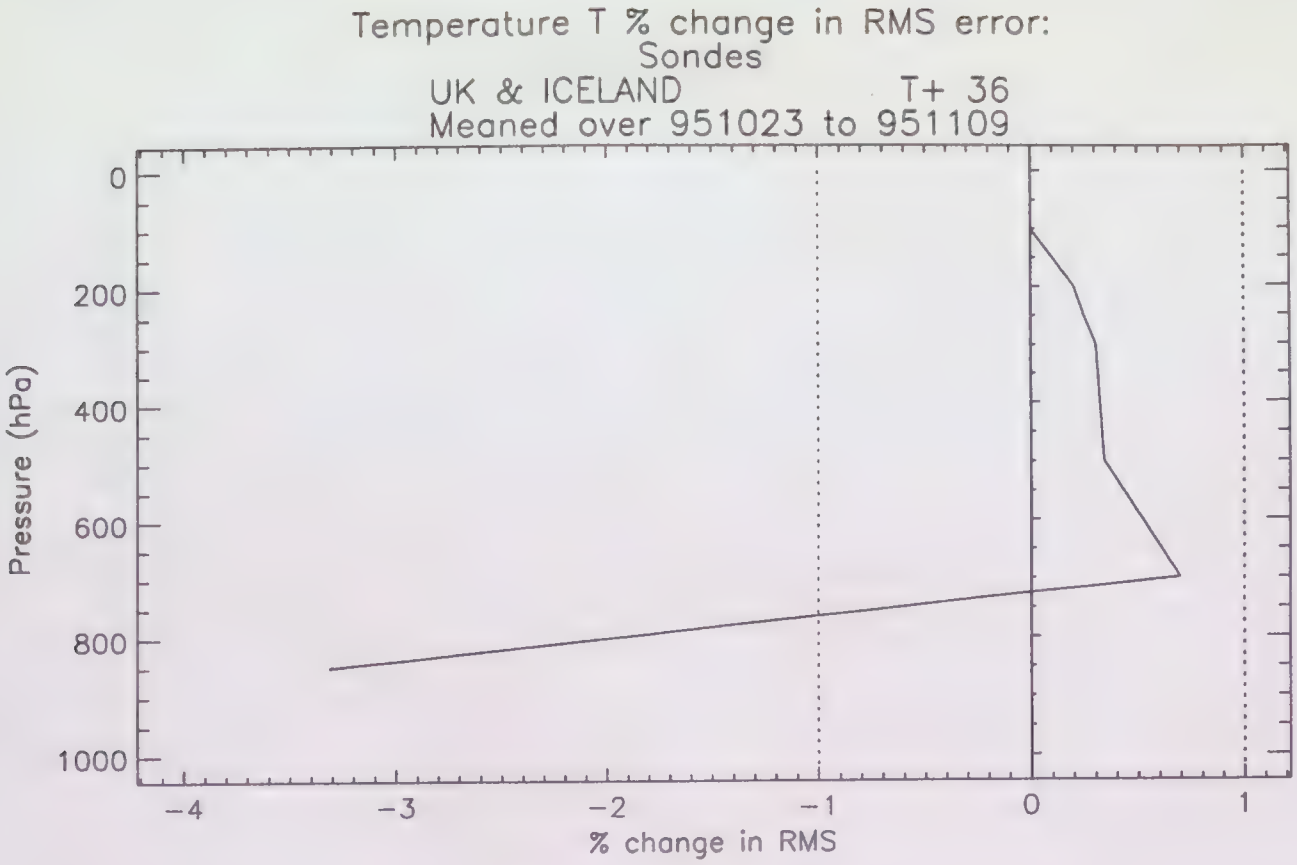

Temperature T % change in RMS error:
Sondes
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−4
−3
−2
−1
0
1
% change in RMS

FIGURE 2. 25

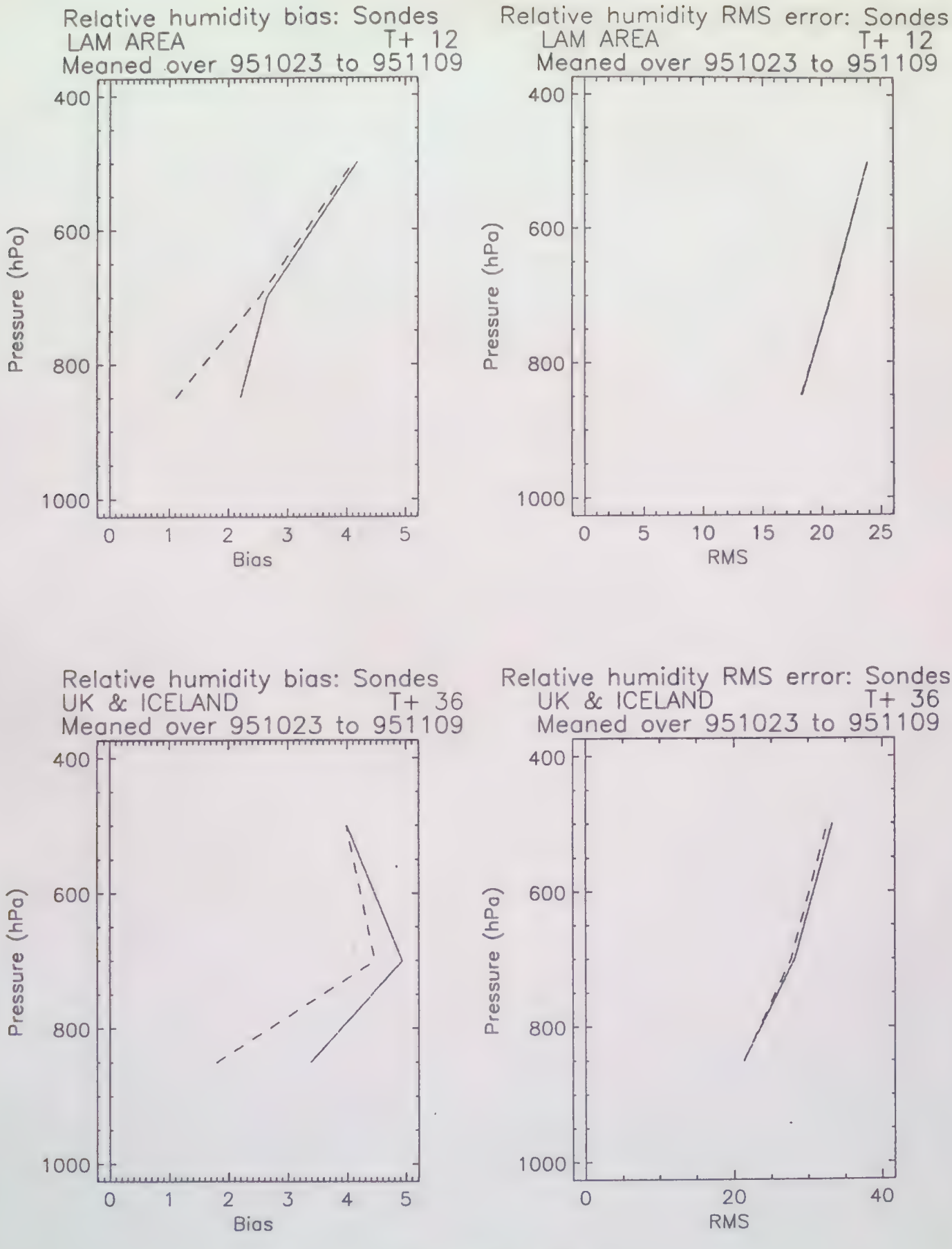

Relative humidity bias: Sondes
LAM AREA T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
400
600
800
1000
0 1 2 3 4 5
Bias
Relative humidity RMS error: Sondes
LAM AREA T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
400
600
800
1000
0 5 10 15 20 25
RMS
Relative humidity bias: Sondes
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
400
600
800
1000
0 1 2 3 4 5
Bias
Relative humidity RMS error: Sondes
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
400
600
800
1000
0 20 40
RMS

FIGURE 2. 26

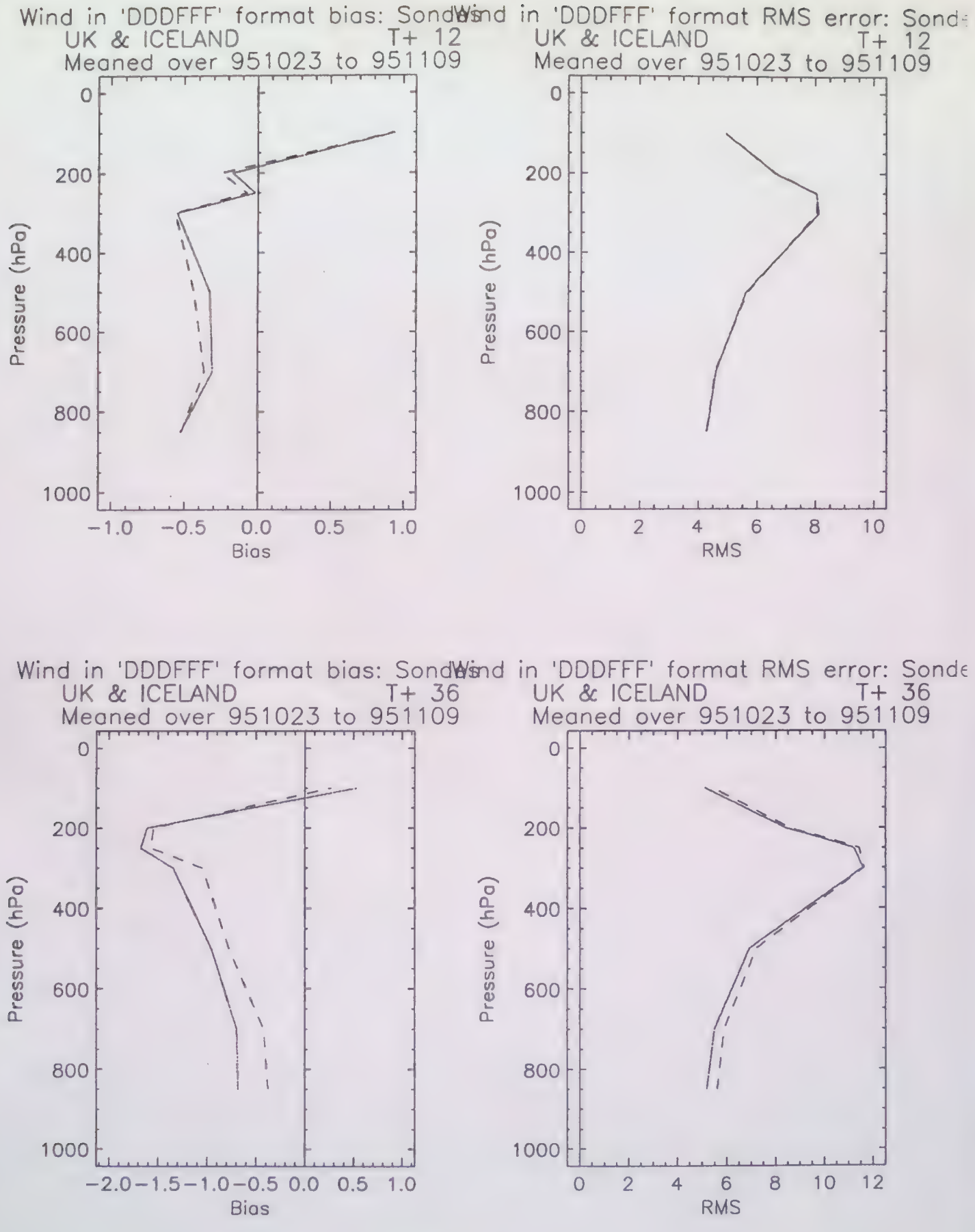
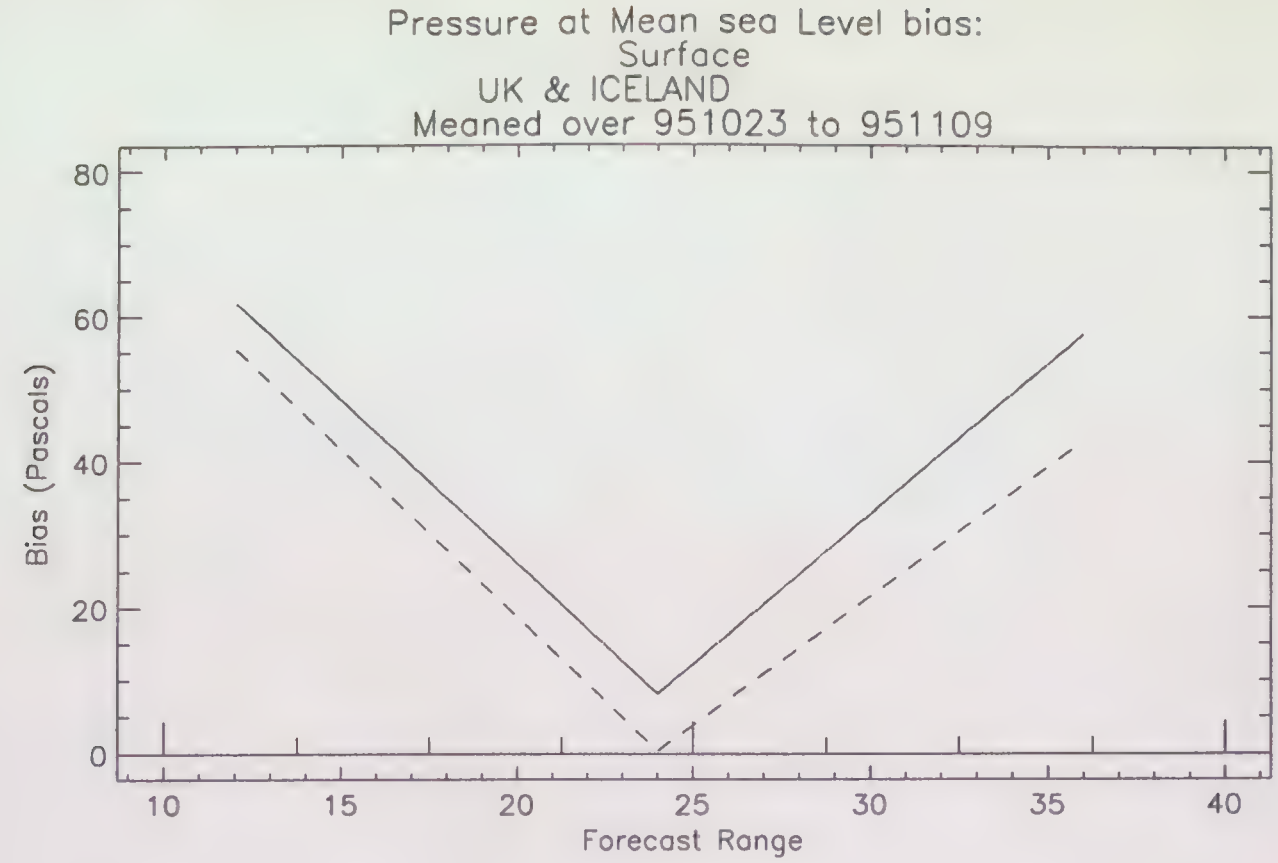

Wind in 'DDDFFF' format bias: Sondes
UK & ICELAND T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−1.0 −0.5 0.0 0.5 1.0
Bias
Wind in 'DDDFFF' format RMS error: Sonde
UK & ICELAND T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0 2 4 6 8 10
RMS
Wind in 'DDDFFF' format bias: Sondes
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
−2.0 −1.5 −1.0 −0.5 0.0 0.5 1.0
Bias
Wind in 'DDDFFF' format RMS error: Sonde
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
0 2 4 6 8 10 12
RMS

FIGURE 2. 27


Pressure at Mean sea Level bias:
Surface
UK & ICELAND
Meaned over 951023 to 951109
Bias (Pascals)
80
60
40
20
0
10
15
20
25
30
35
40
Forecast Range

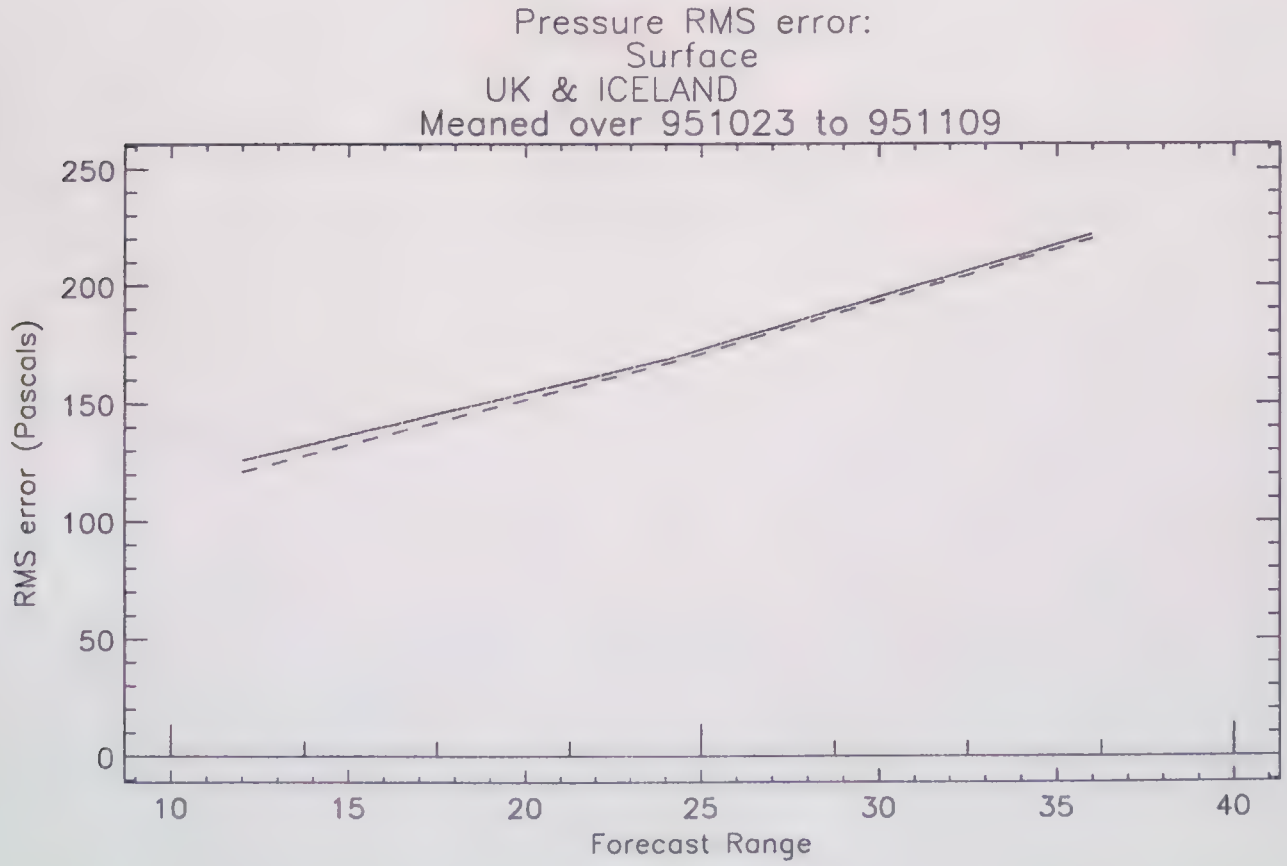
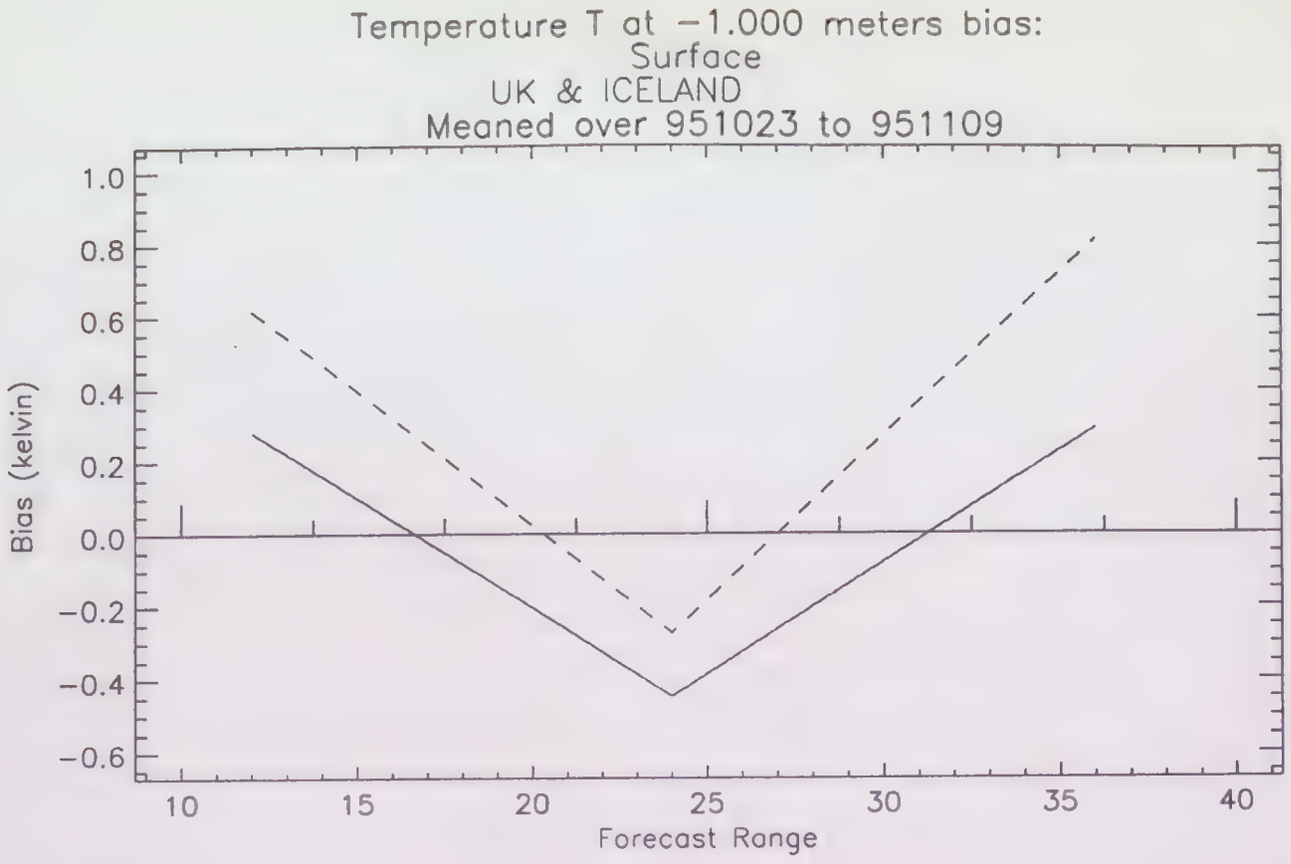

Pressure RMS error:
Surface
UK & ICELAND
Meaned over 951023 to 951109
RMS error (Pascals)
250
200
150
100
50
0
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 28


Temperature T at −1.000 meters bias:
Surface
UK & ICELAND
Meaned over 951023 to 951109
Bias (kelvin)
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
10
15
20
25
30
35
40
Forecast Range

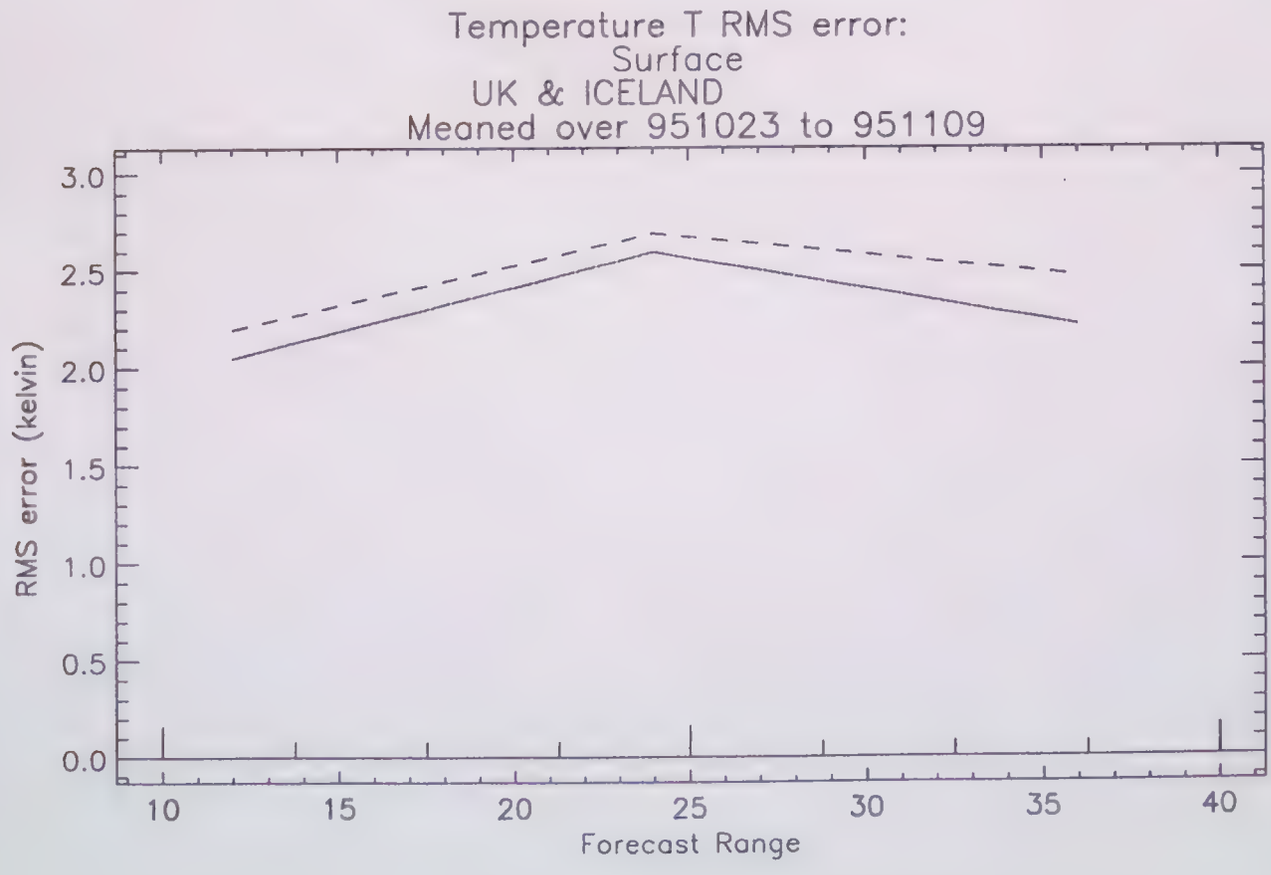
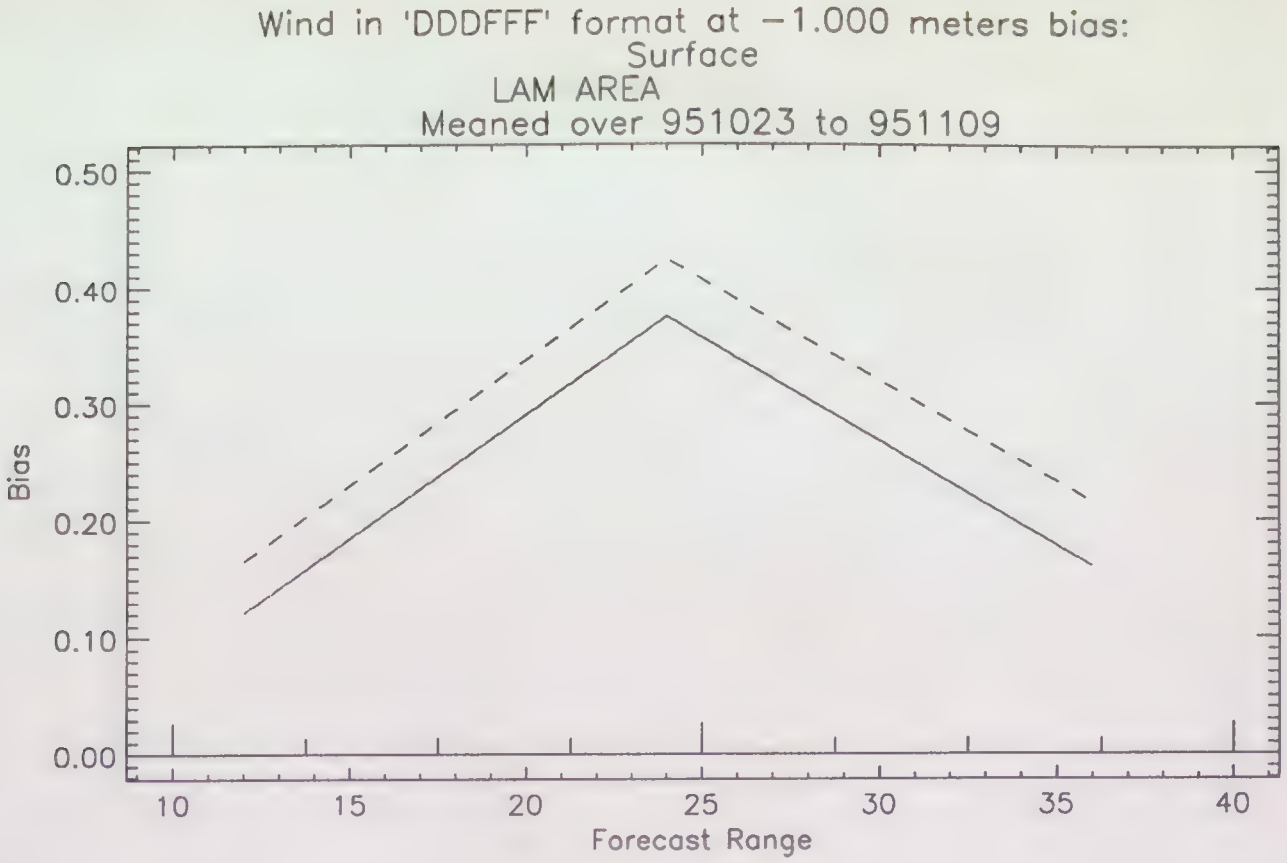

Temperature T RMS error:
Surface
UK & ICELAND
Meaned over 951023 to 951109
RMS error (kelvin)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 29


Wind in 'DDDFFF' format at −1.000 meters bias:
Surface
LAM AREA
Meaned over 951023 to 951109
Bias
0.50
0.40
0.30
0.20
0.10
0.00
10
15
20
25
30
35
40
Forecast Range

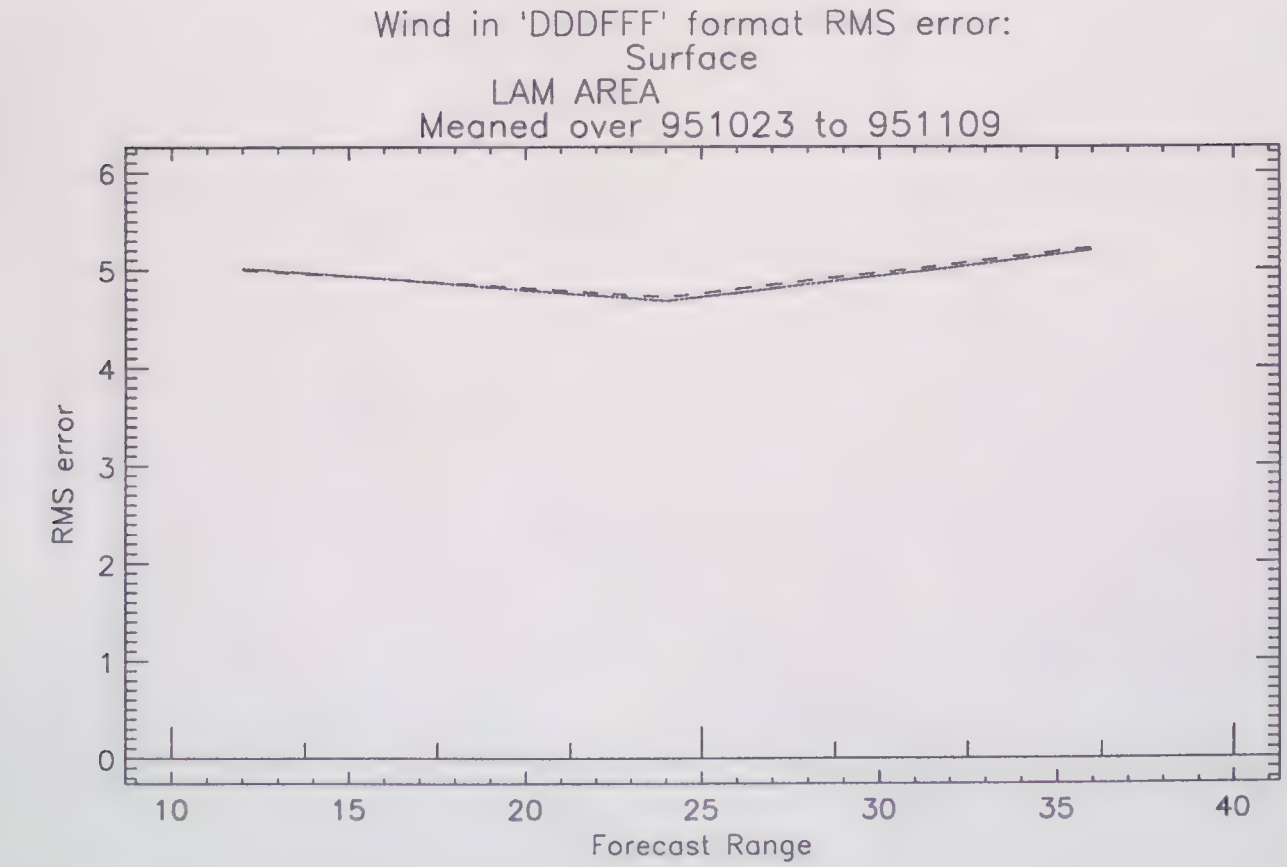
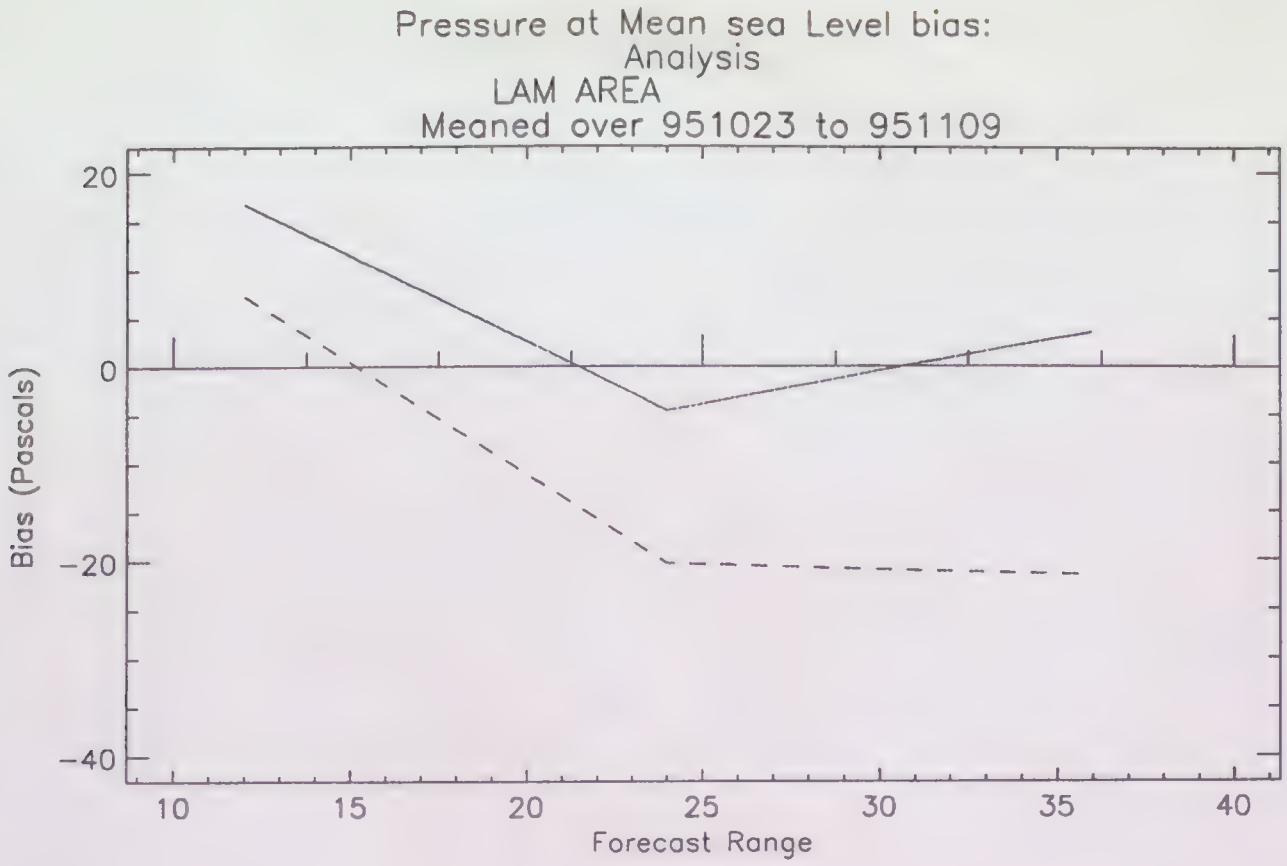

Wind in 'DDDFFF' format RMS error:
Surface
LAM AREA
Meaned over 951023 to 951109
RMS error
6
5
4
3
2
1
0
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 30


Pressure at Mean sea Level bias:
Analysis
LAM AREA
Meaned over 951023 to 951109
Bias (Pascals)
20
0
-20
-40
10
15
20
25
30
35
40
Forecast Range

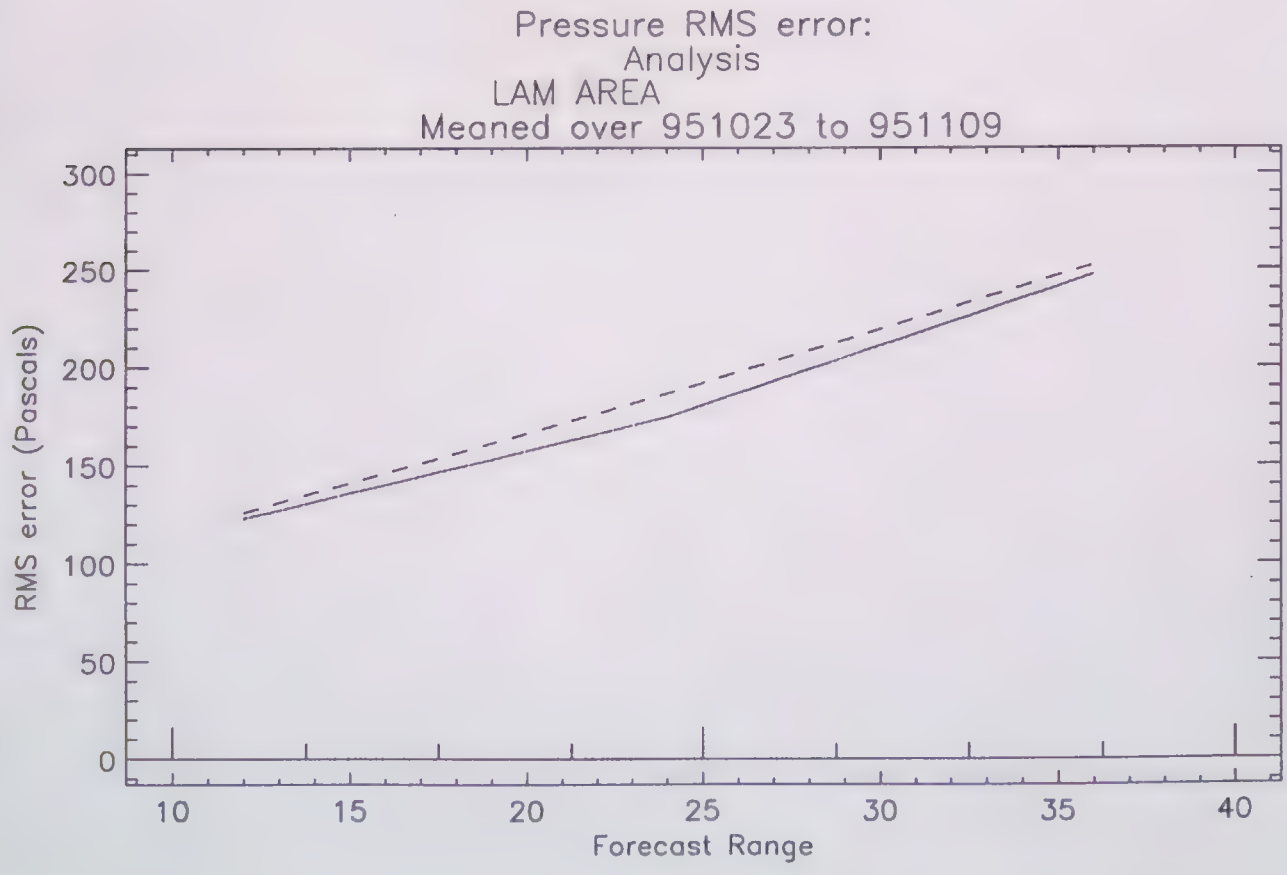

Pressure RMS error:
Analysis
LAM AREA
Meaned over 951023 to 951109
RMS error (Pascals)
300
250
200
150
100
50
0
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 31

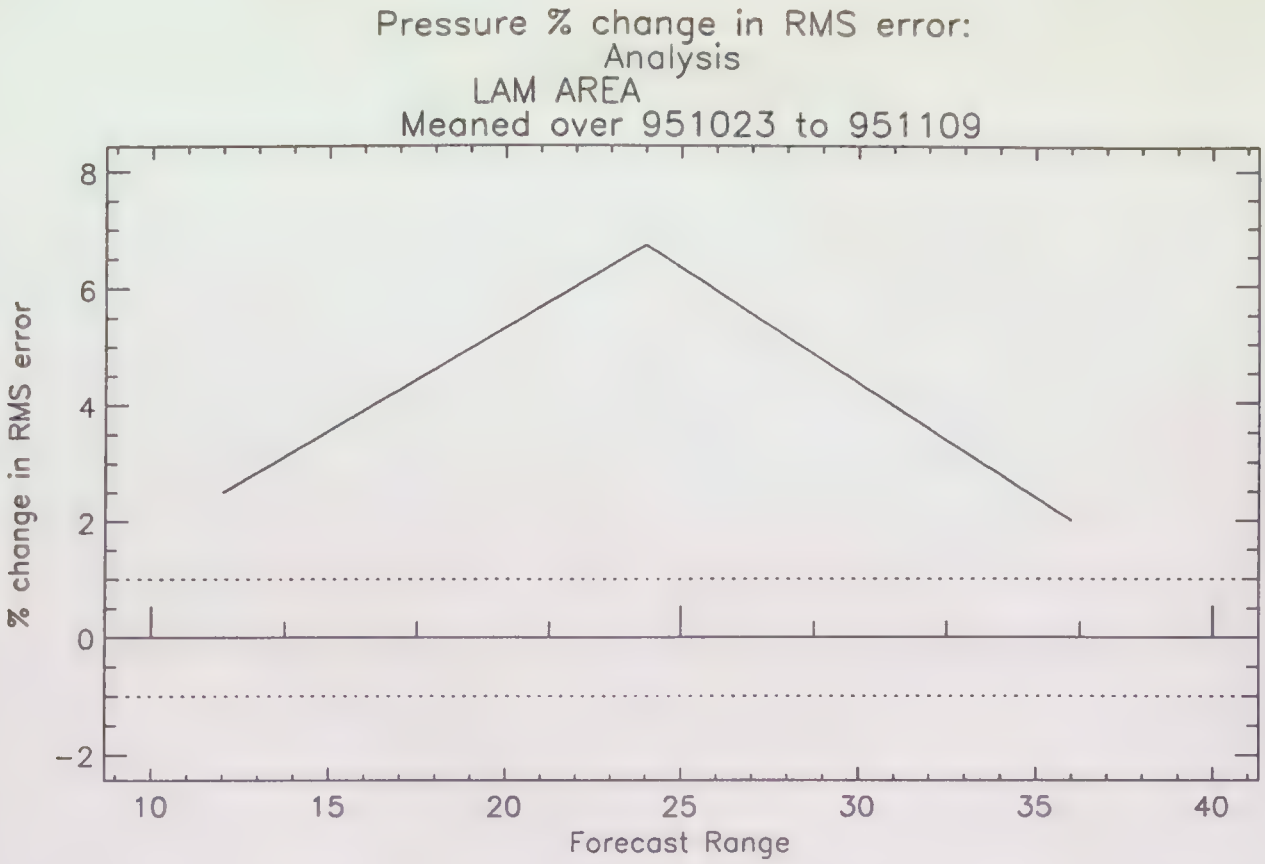

Pressure % change in RMS error:
Analysis
LAM AREA
Meaned over 951023 to 951109
% change in RMS error
8
6
4
2
0
−2
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 32

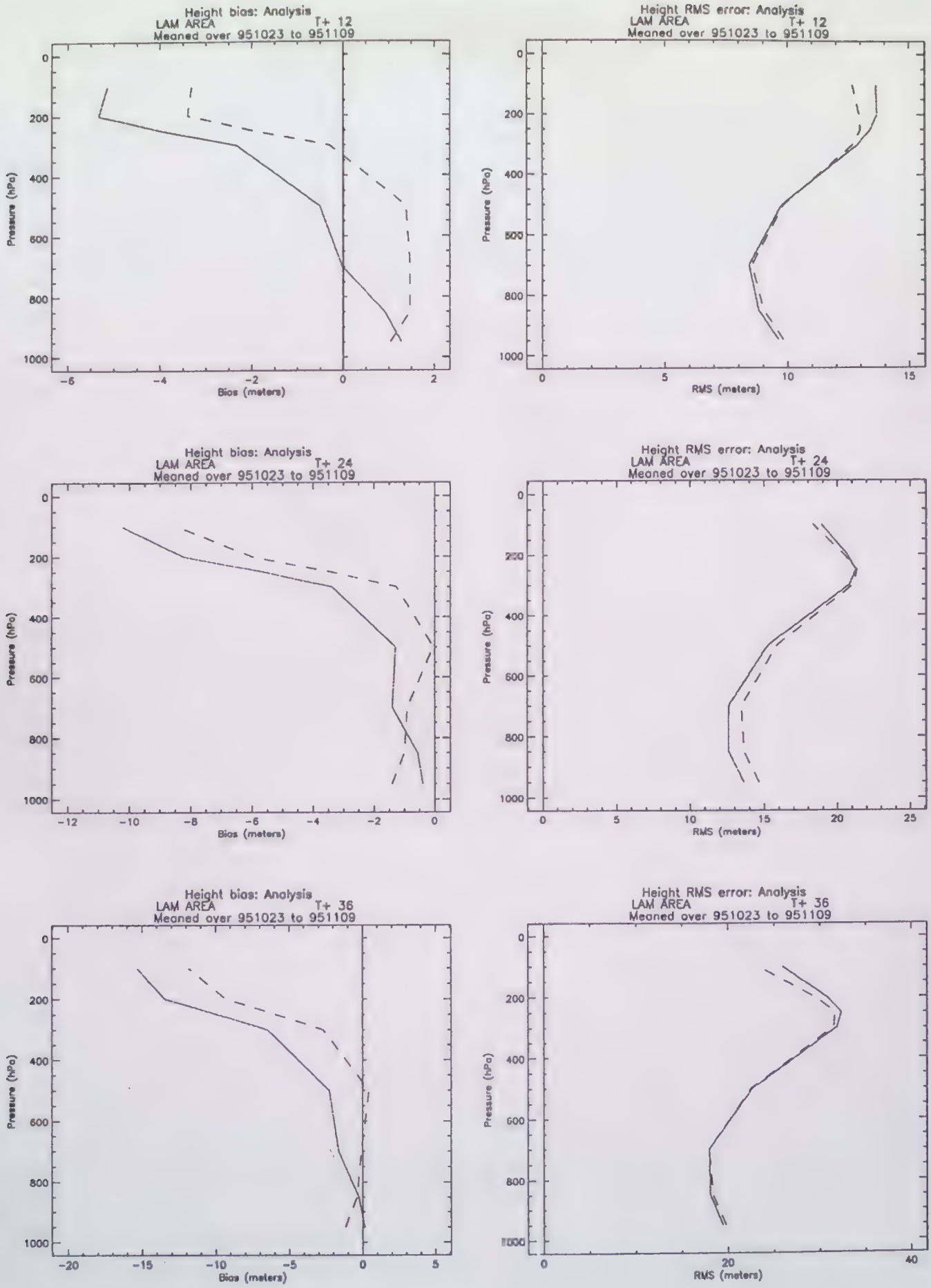

Height bias: Analysis
LAM AREA T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
Bias (meters)
Height RMS error: Analysis
LAM AREA T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
RMS (meters)
Height bias: Analysis
LAM AREA T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
Bias (meters)
Height RMS error: Analysis
LAM AREA T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
RMS (meters)
Height bias: Analysis
LAM AREA T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
Bias (meters)
Height RMS error: Analysis
LAM AREA T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
RMS (meters)

FIGURE 2. 33

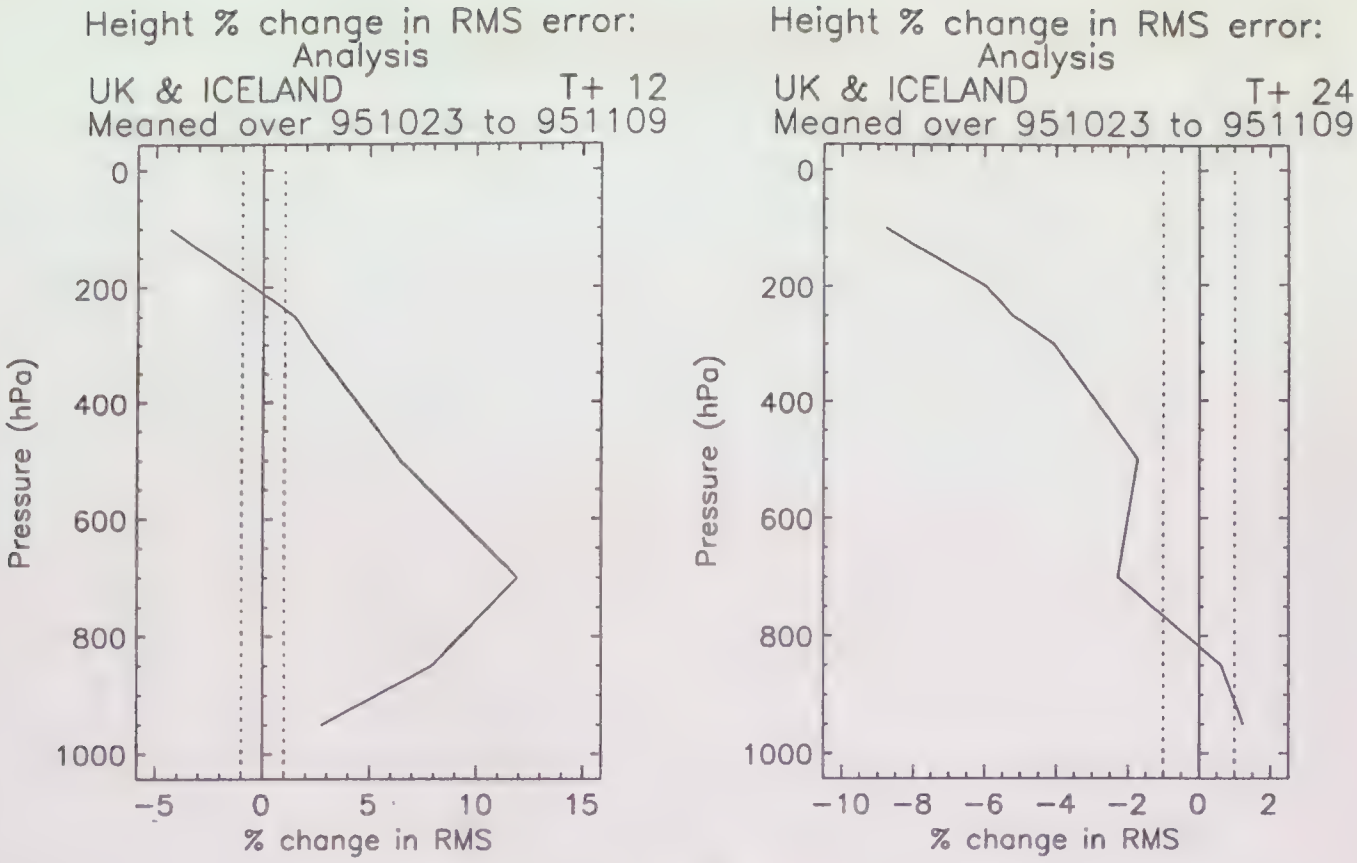

Height % change in RMS error:
Analysis
UK & ICELAND T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−5
0
5
10
15
% change in RMS
Height % change in RMS error:
Analysis
UK & ICELAND T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−10
−8
−6
−4
−2
0
2
% change in RMS

FIGURE 2. 34

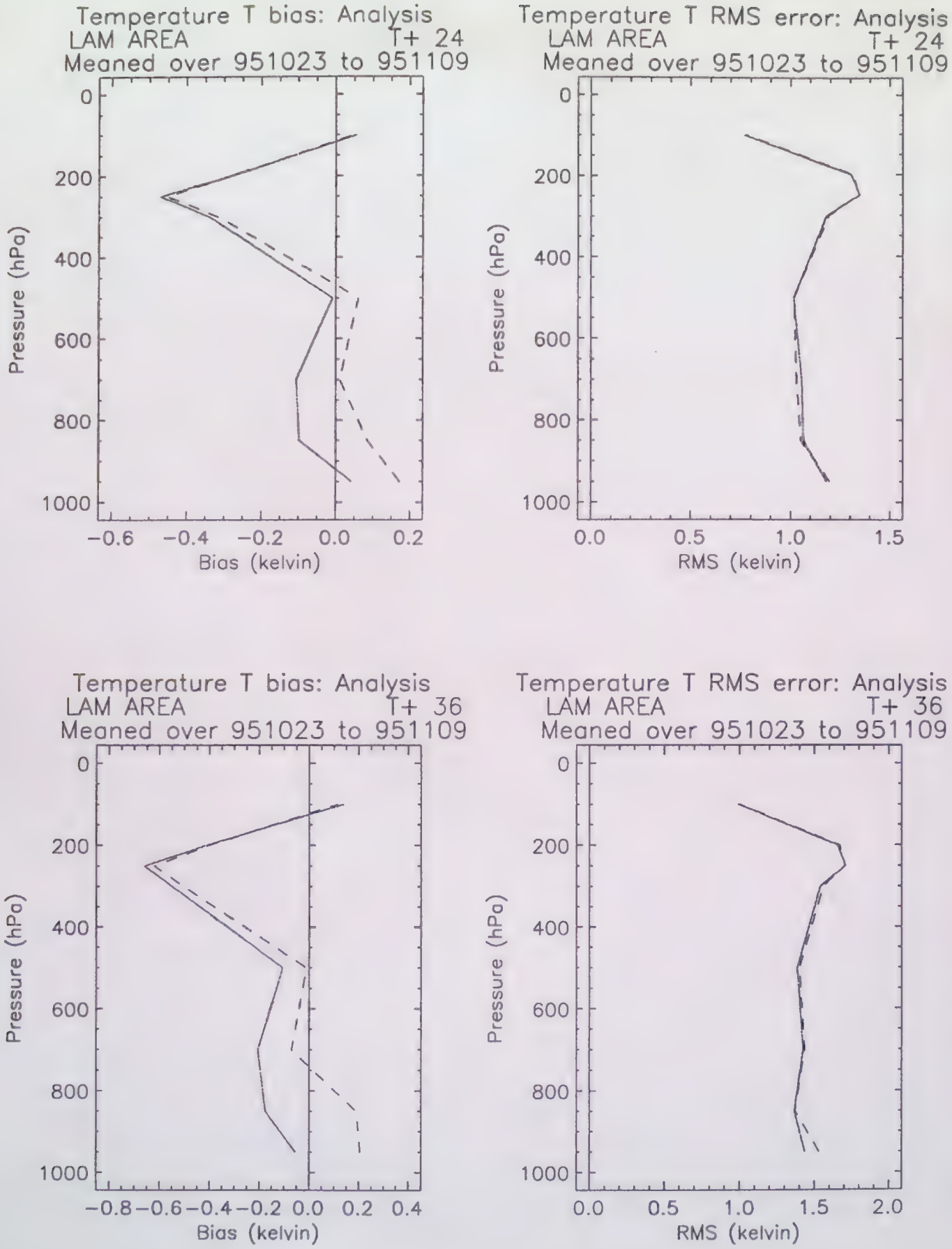
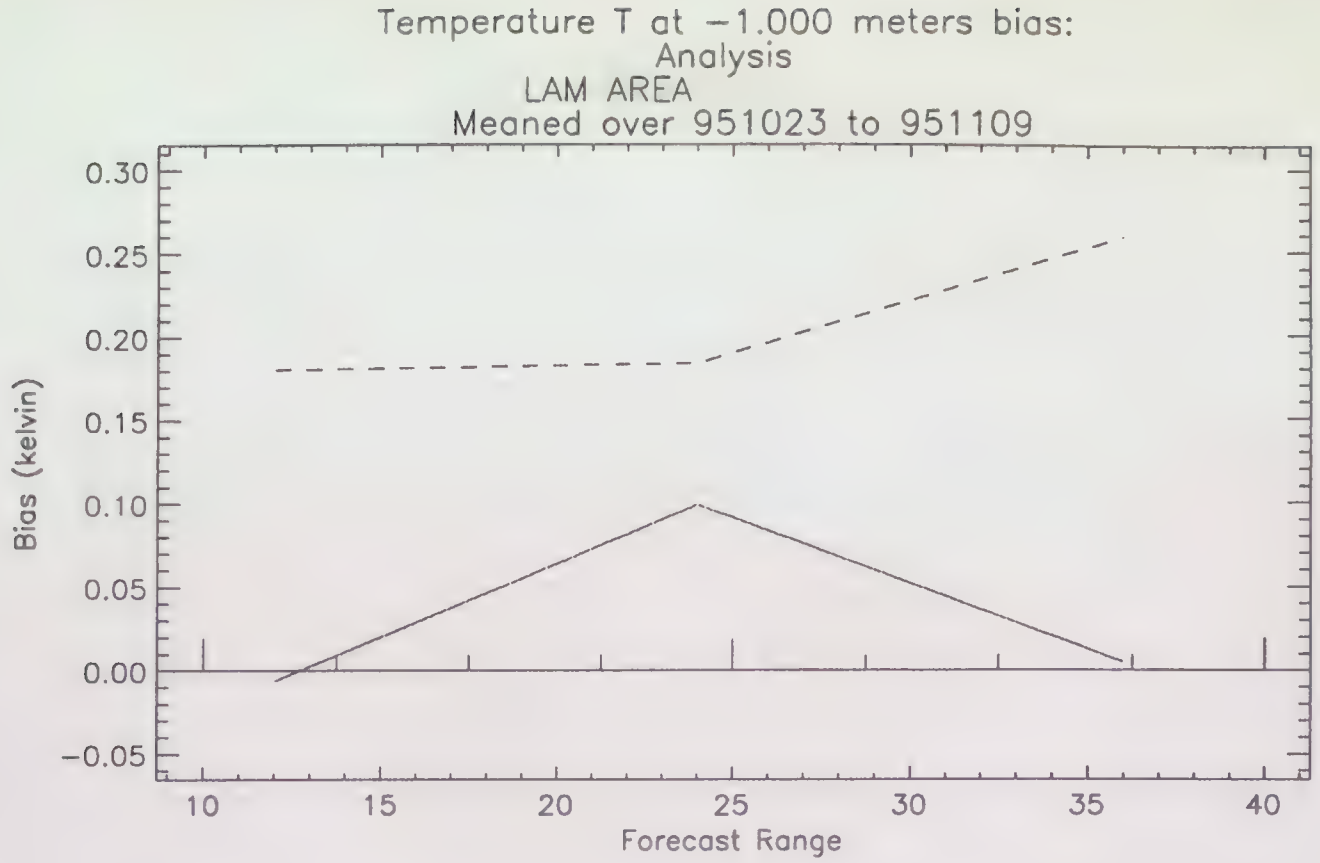

Temperature T bias: Analysis
LAM AREA T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−0.6 −0.4 −0.2 0.0 0.2
Bias (kelvin)
Temperature T RMS error: Analysis
LAM AREA T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
0.0 0.5 1.0 1.5
RMS (kelvin)
Temperature T bias: Analysis
LAM AREA T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
−0.8 −0.6 −0.4 −0.2 0.0 0.2 0.4
Bias (kelvin)
Temperature T RMS error: Analysis
LAM AREA T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
0.0 0.5 1.0 1.5 2.0
RMS (kelvin)

FIGURE 2. 35


Temperature T at −1.000 meters bias:
Analysis
LAM AREA
Meaned over 951023 to 951109
Bias (kelvin)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
10
15
20
25
30
35
40
Forecast Range

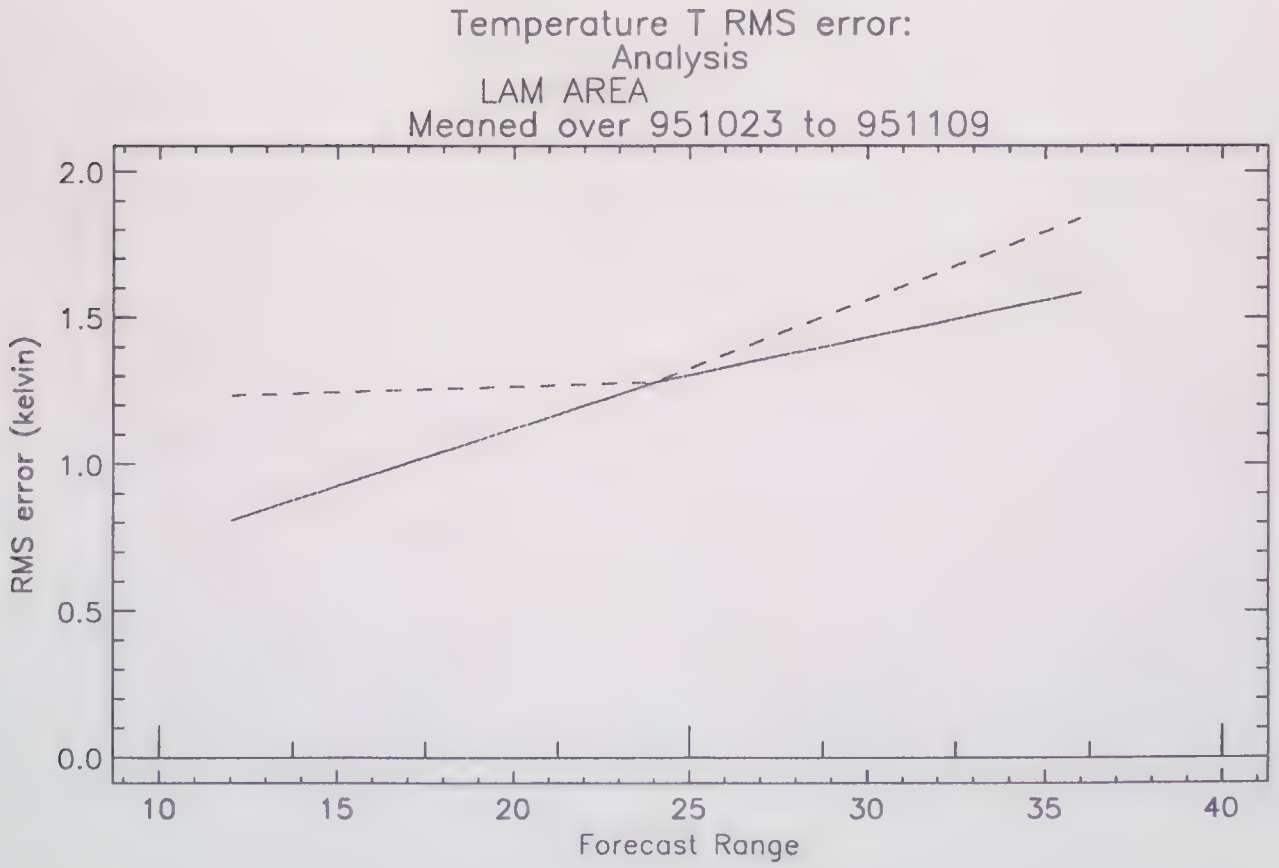

Temperature T RMS error:
Analysis
LAM AREA
Meaned over 951023 to 951109
RMS error (kelvin)
2.0
1.5
1.0
0.5
0.0
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 36

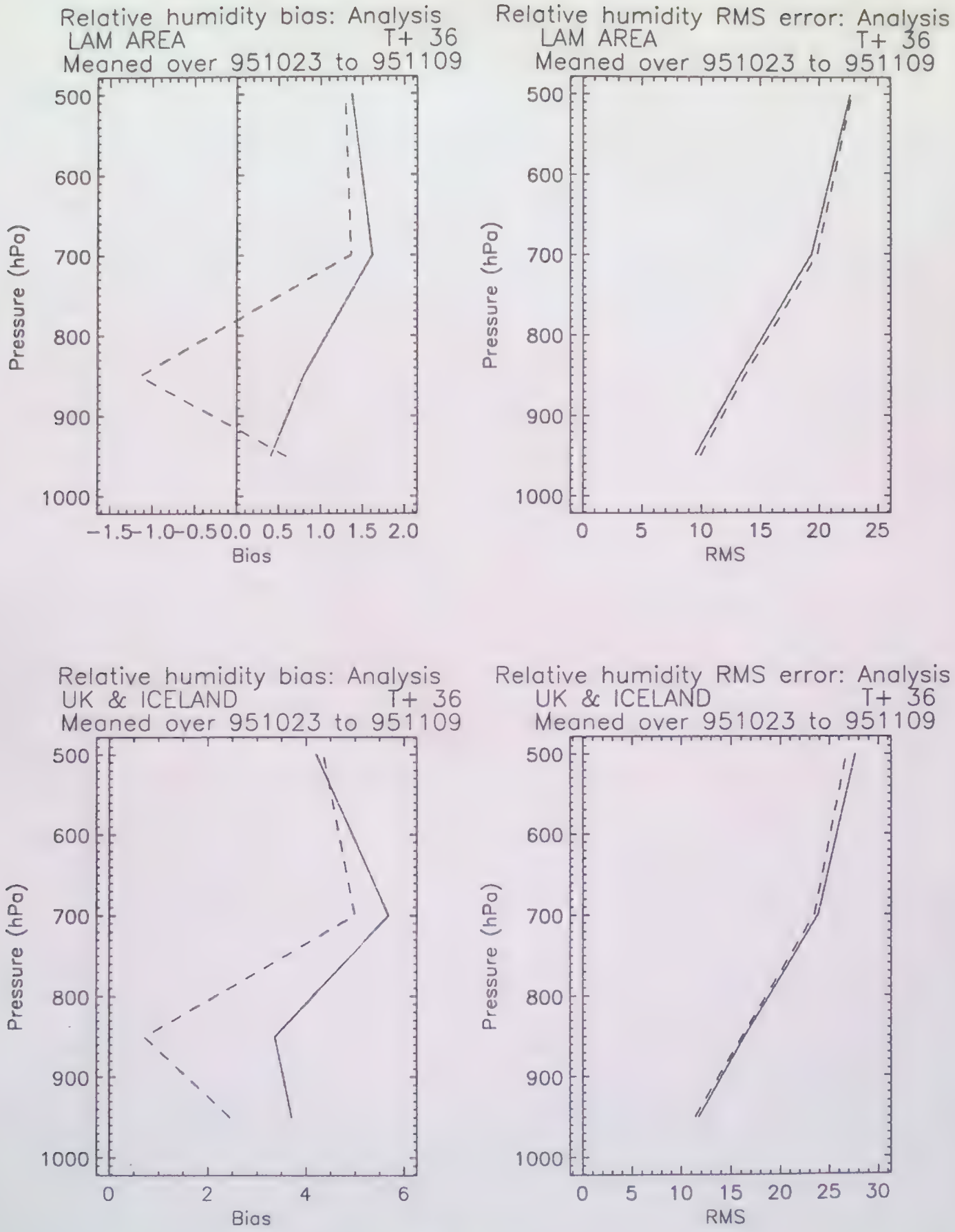

Relative humidity bias: Analysis
LAM AREA T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
500
600
700
800
900
1000
−1.5 −1.0 −0.5 0.0 0.5 1.0 1.5 2.0
Bias
Relative humidity RMS error: Analysis
LAM AREA T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
500
600
700
800
900
1000
0 5 10 15 20 25
RMS
Relative humidity bias: Analysis
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
500
600
700
800
900
1000
0 2 4 6
Bias
Relative humidity RMS error: Analysis
UK & ICELAND T+ 36
Meaned over 951023 to 951109
Pressure (hPa)
500
600
700
800
900
1000
0 5 10 15 20 25 30
RMS

FIGURE 2. 37

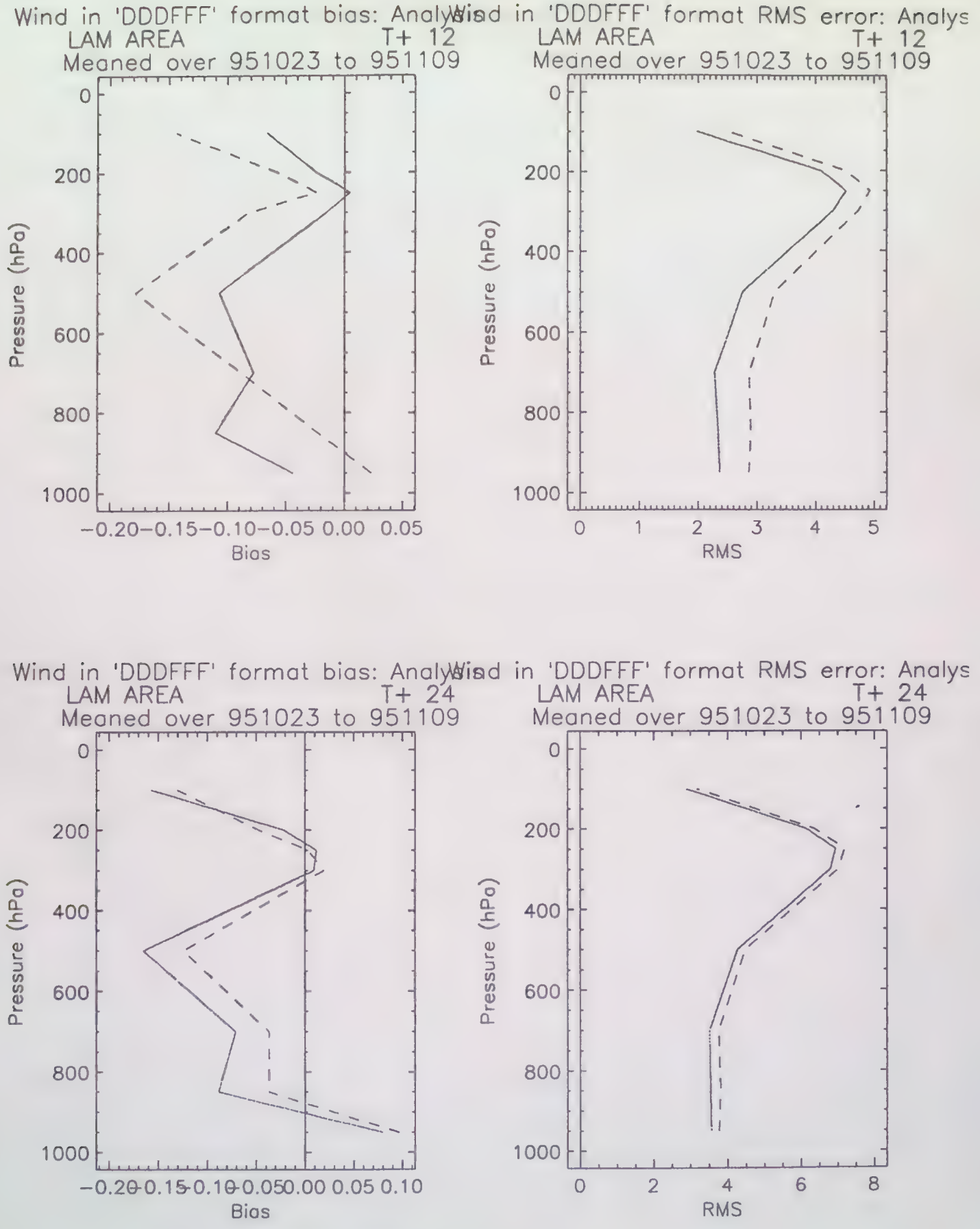
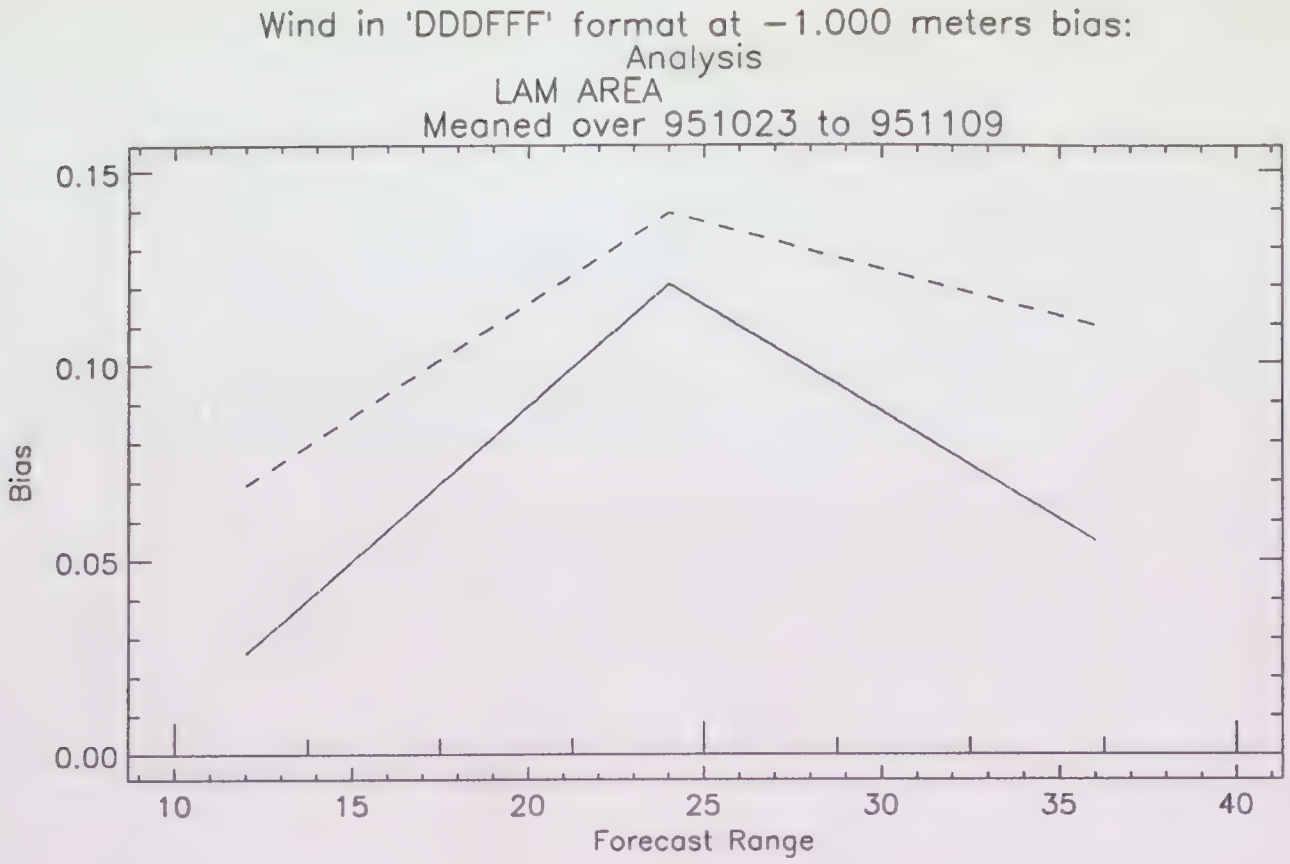

Wind in 'DDDFFF' format bias: Analysis
LAM AREA T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0
200
400
600
800
1000
−0.20 −0.15 −0.10 −0.05 0.00 0.05
Bias
Wind in 'DDDFFF' format RMS error: Analysis
LAM AREA T+ 12
Meaned over 951023 to 951109
Pressure (hPa)
0 1 2 3 4 5
RMS
Wind in 'DDDFFF' format bias: Analysis
LAM AREA T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
−0.20 −0.15 −0.10 −0.05 0.00 0.05 0.10
Bias
Wind in 'DDDFFF' format RMS error: Analysis
LAM AREA T+ 24
Meaned over 951023 to 951109
Pressure (hPa)
0 2 4 6 8
RMS

FIGURE 2. 38


Wind in 'DDDFFF' format at −1.000 meters bias:
Analysis
LAM AREA
Meaned over 951023 to 951109
0.15
0.10
0.05
0.00
Bias
10
15
20
25
30
35
40
Forecast Range

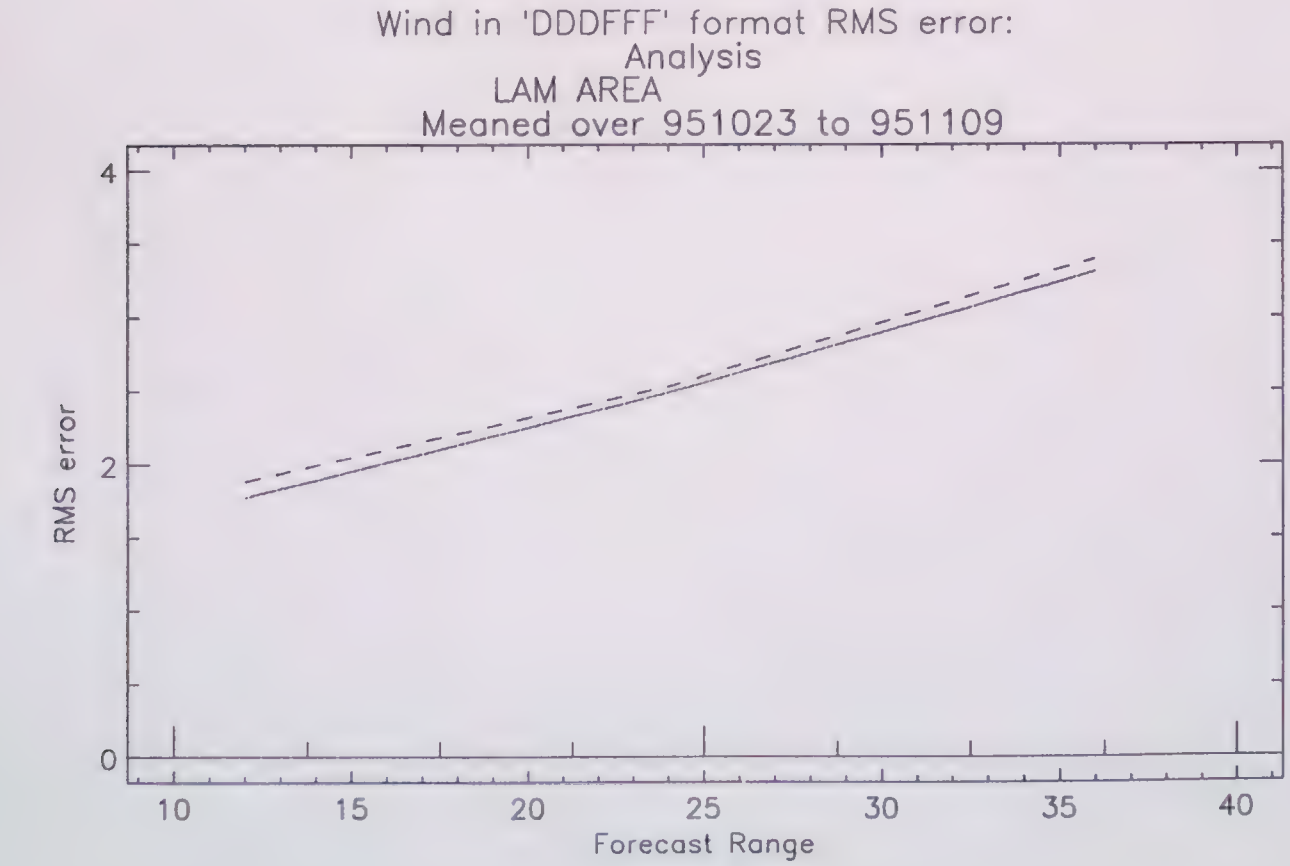

Wind in 'DDDFFF' format RMS error:
Analysis
LAM AREA
Meaned over 951023 to 951109
4
2
0
RMS error
10
15
20
25
30
35
40
Forecast Range

FIGURE 2. 39

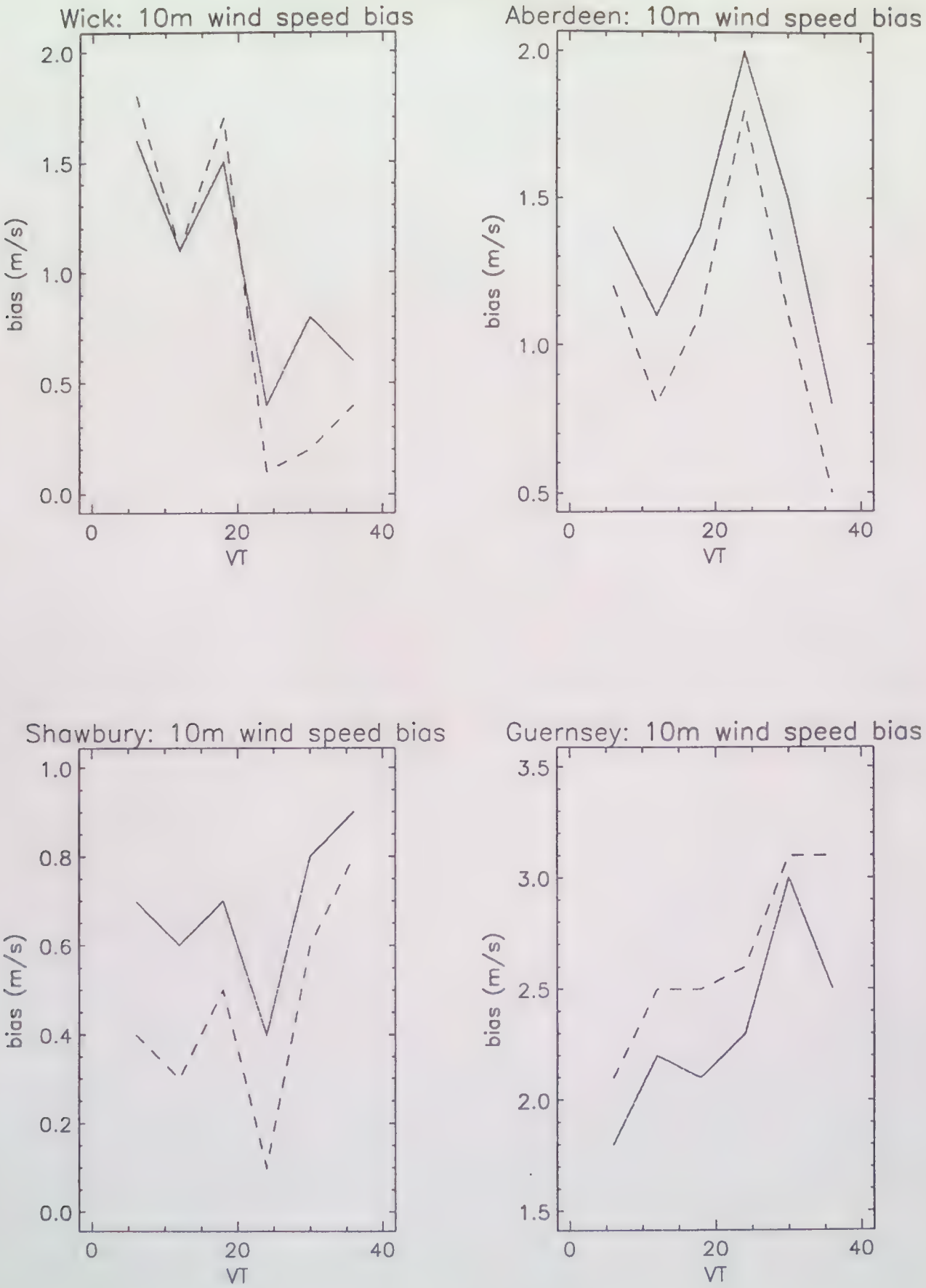

Wick: 10m wind speed bias
bias (m/s)
2.0
1.5
1.0
0.5
0.0
0
20
40
VT
Aberdeen: 10m wind speed bias
bias (m/s)
2.0
1.5
1.0
0.5
0
20
40
VT
Shawbury: 10m wind speed bias
bias (m/s)
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
VT
Guernsey: 10m wind speed bias
bias (m/s)
3.5
3.0
2.5
2.0
1.5
0
20
40
VT

FIGURE 2. 40

T+120 FORECASTS MEANED OVER PERIOD 12Z 13/11/95 TO 12Z 02/12/95
PARALLEL SUITE TRIAL OF COMPONENTS OF 3CV PHYSICS
TRIAL - OPERATIONAL DIFFERENCES ALSO SHOWN (contours 0.5hPa)
negative differences shaded, positive differences - pecked lines

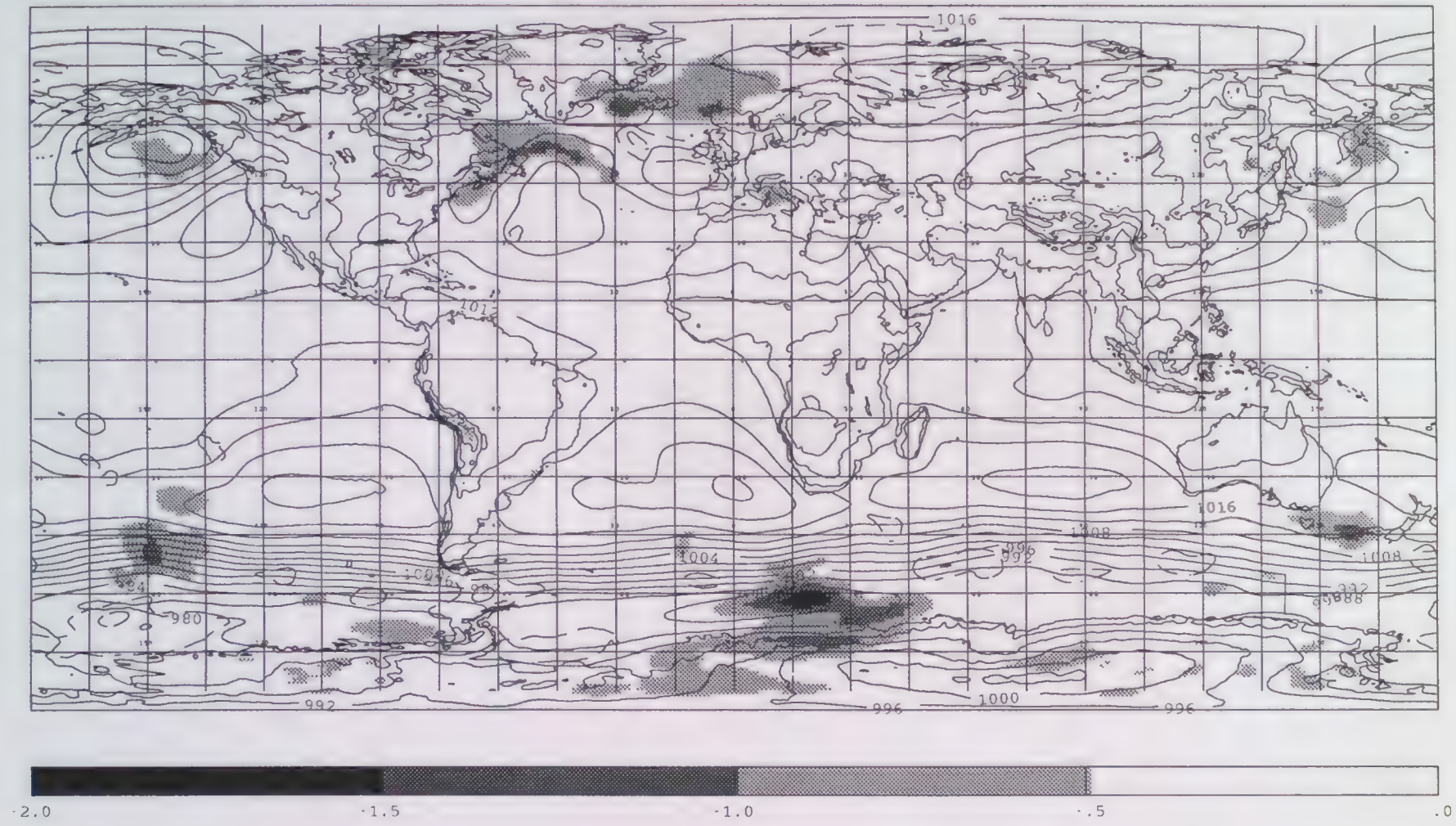
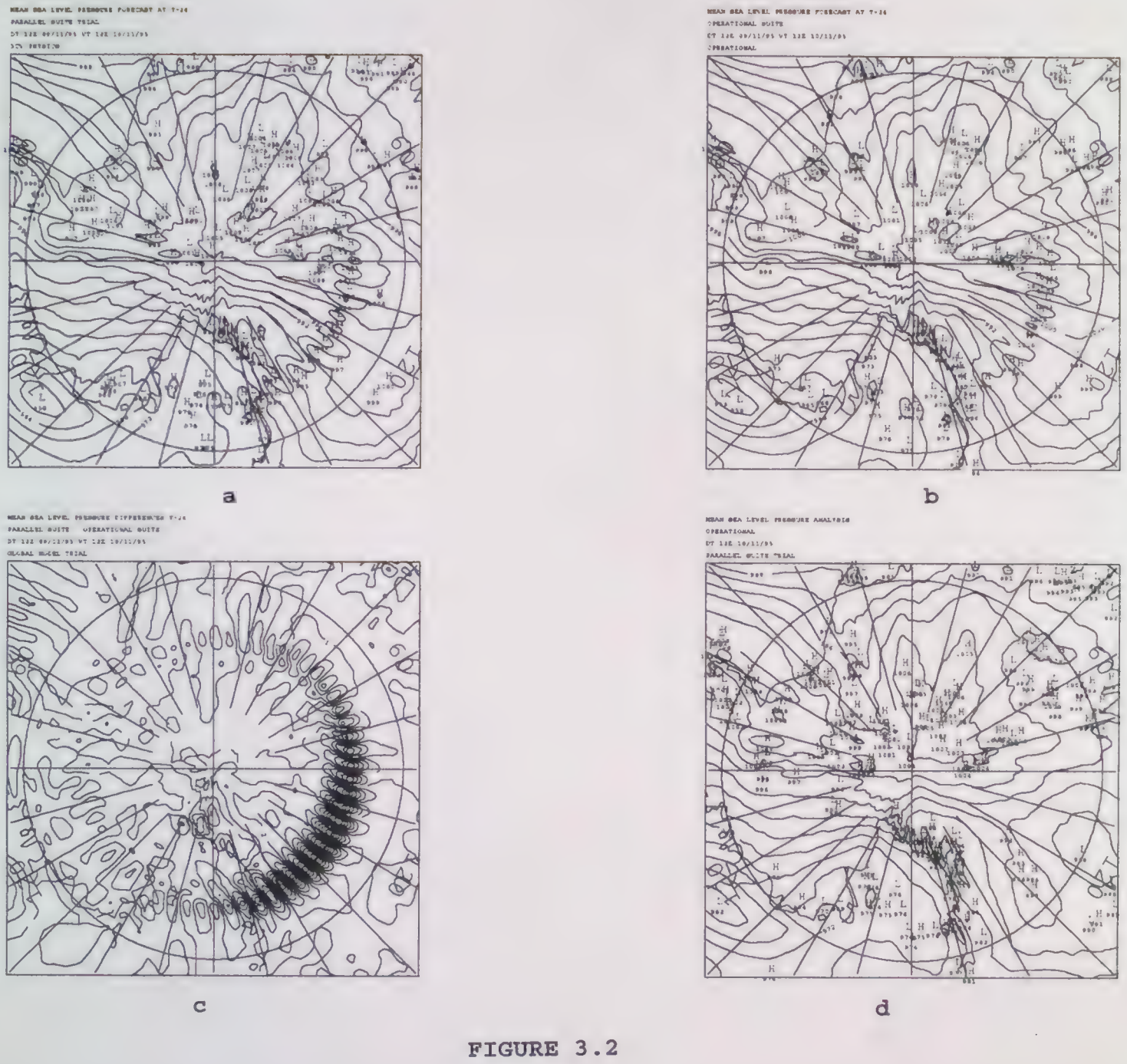


FIGURE 3.1



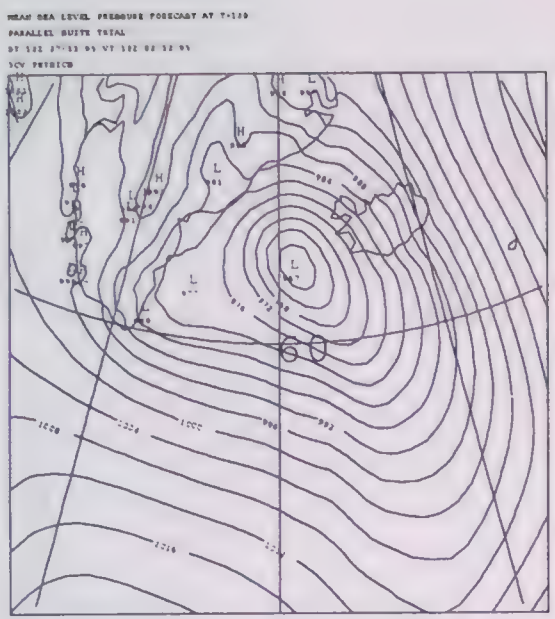
a

b

c

d

FIGURE 3.2



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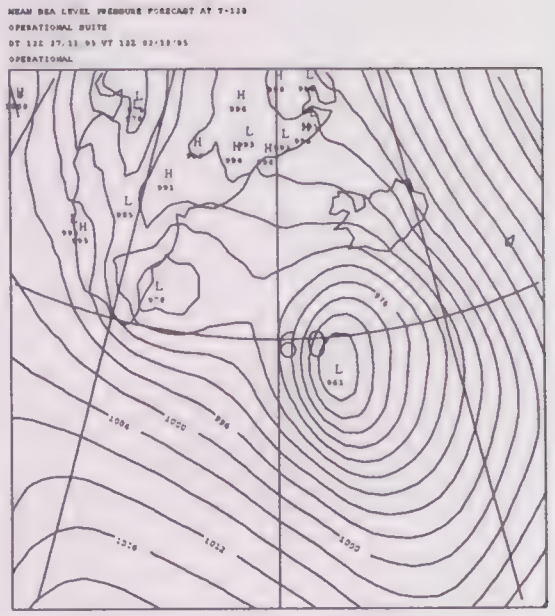

b

c

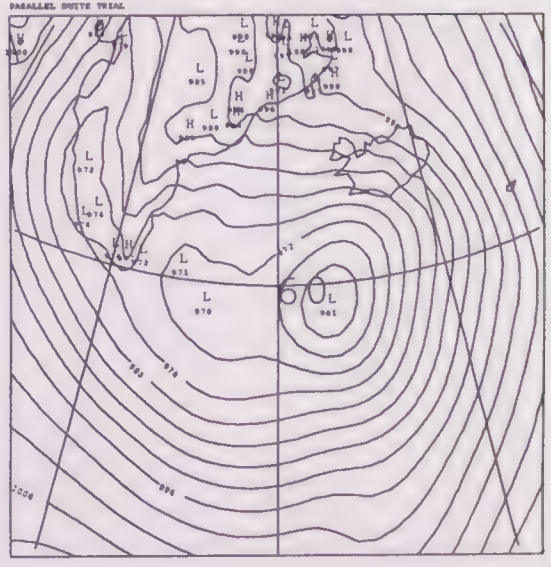

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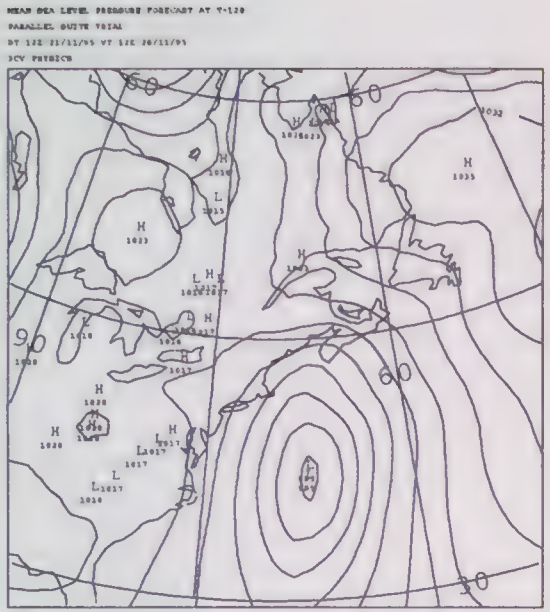
FIGURE 3.3



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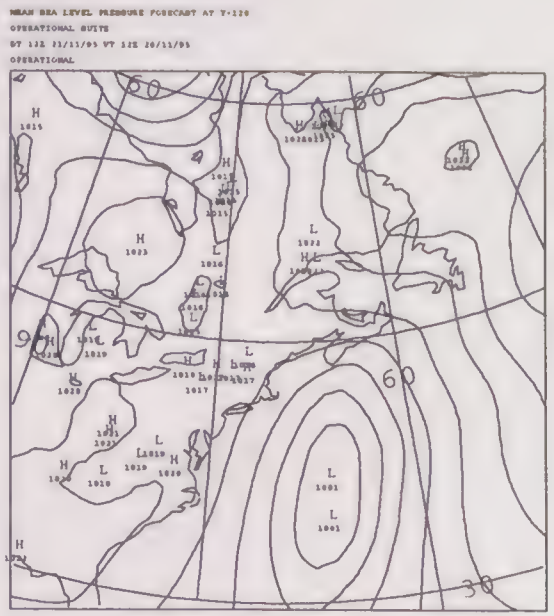

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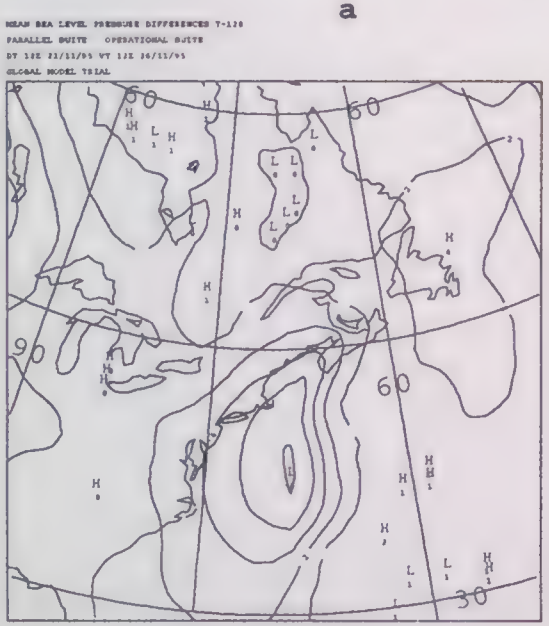

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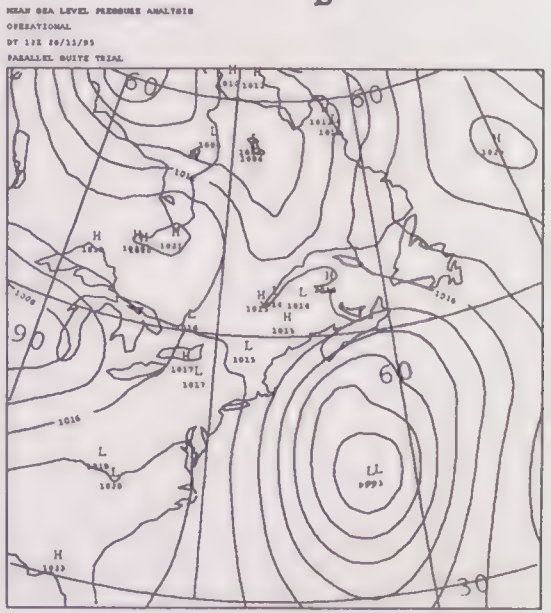
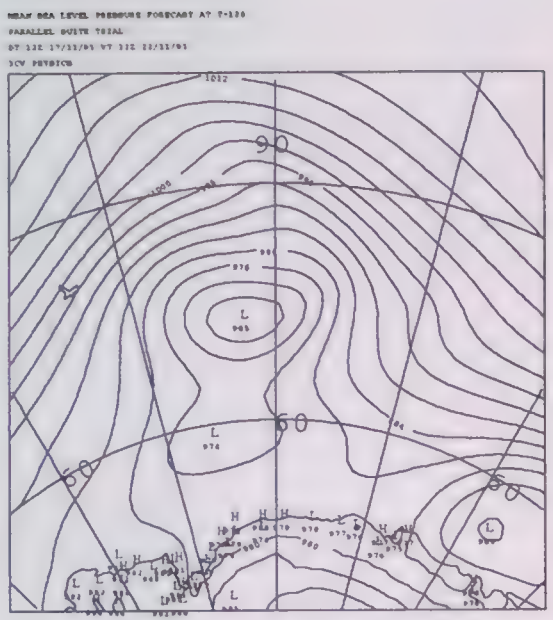


d

FIGURE 3.4



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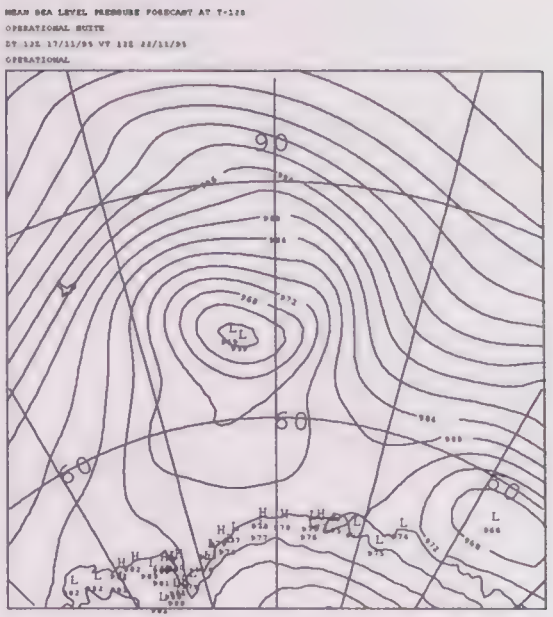

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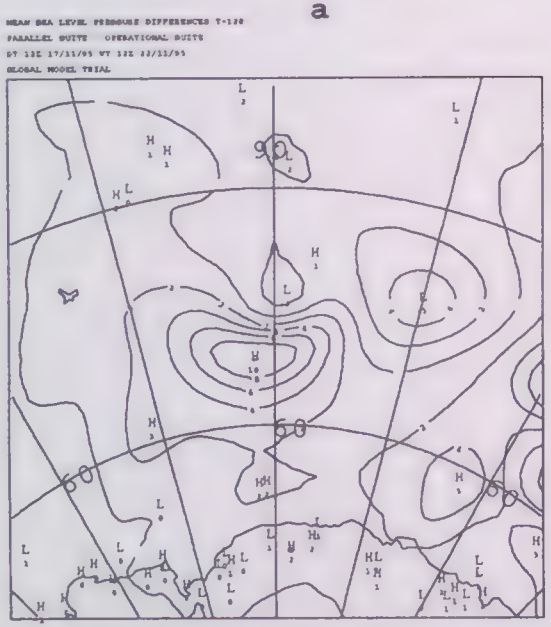

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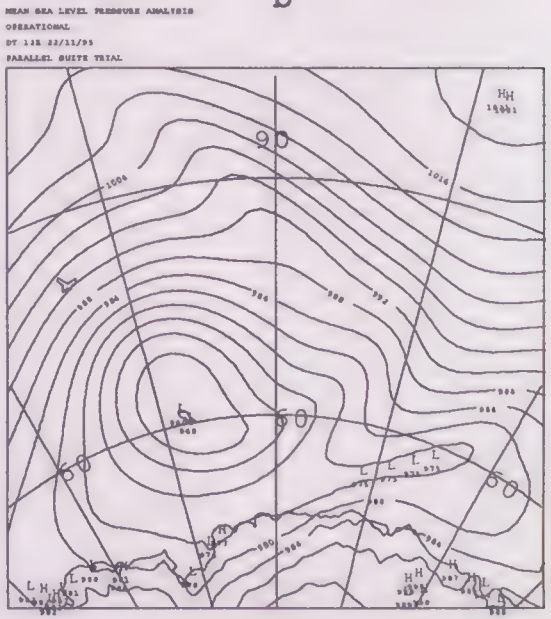
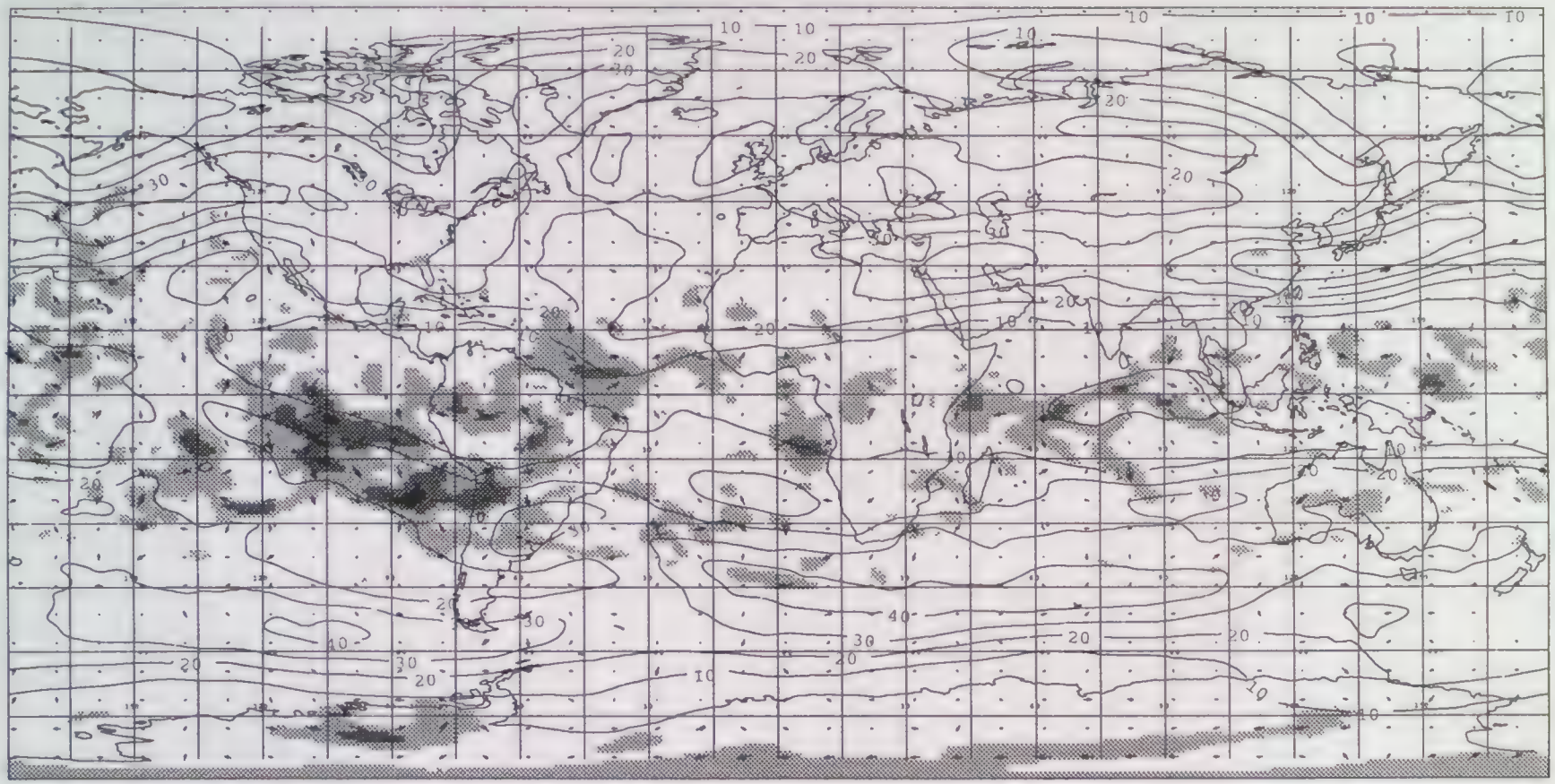


d

FIGURE 3.5

250hPa WIND FORECAST FOR T+24 FROM PARALLEL SUITE TRIAL(COMPONENTS OF 3CV PHYSIC
FORECAST MEANED OVER PERIOD 12Z 09/11/95 TO 12Z 28/11/95
SHADED AREAS INDICATE (TRIAL - OPERATIONAL) DIFFERENCES
WIND ARROWS INDICATE VECTOR DIFFERENCES

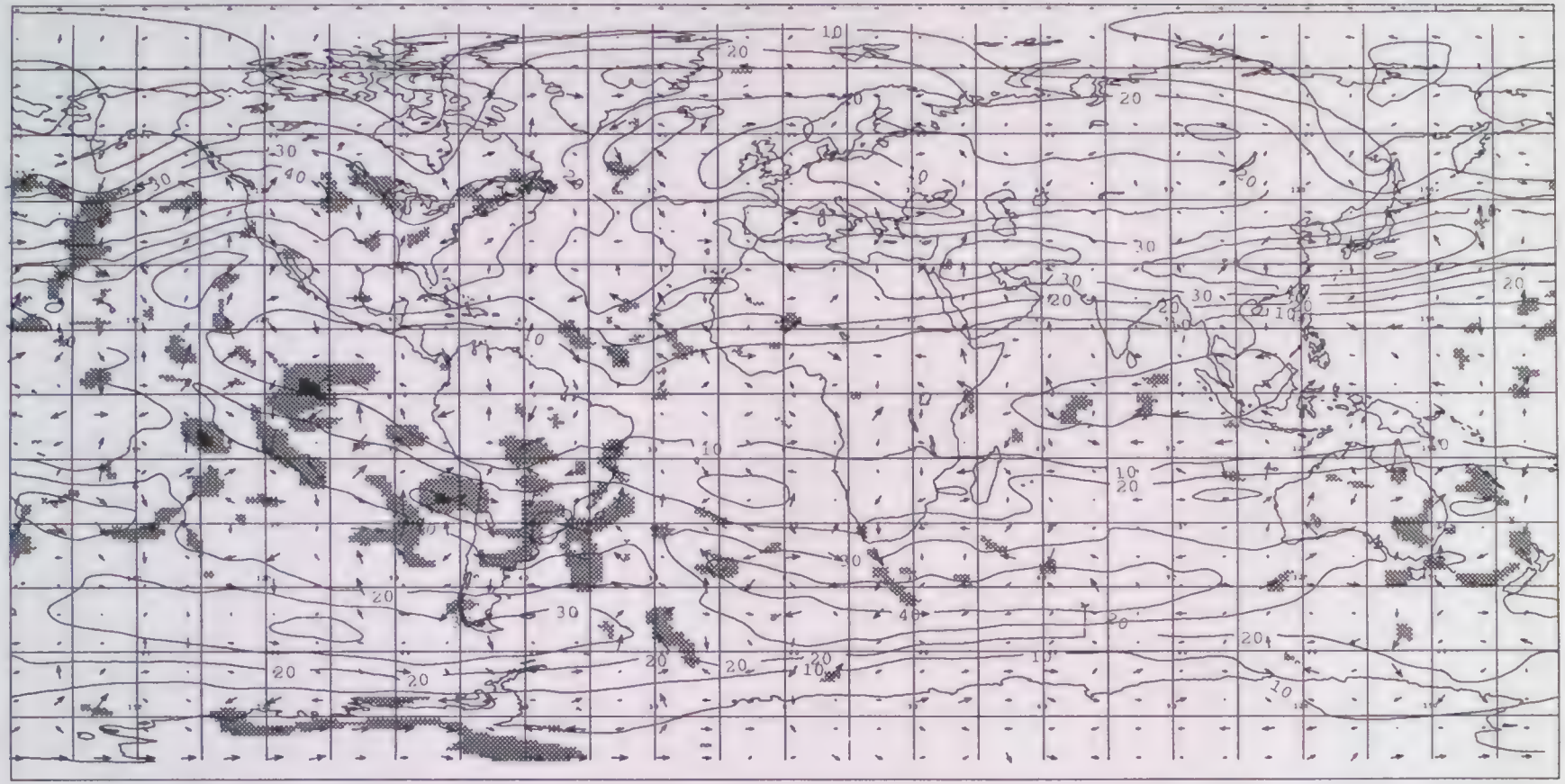


→ REPRESENTS 2 M/S

.0 .5 1.0 1.5 2.0

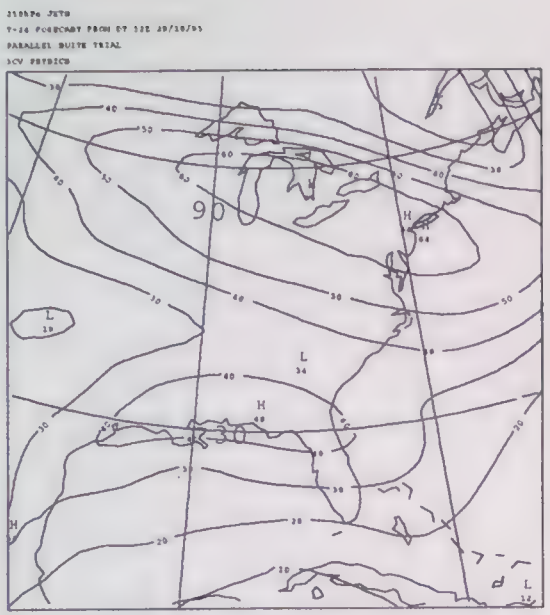
FIGURE 3.6

250hPa WIND FORECAST FOR T+72 FROM PARALLEL SUITE TRIAL(COMPONENTS OF 3CV PHYSIC
FORECAST MEANED OVER PERIOD 12Z 11/11/95 TO 12Z 30/11/95
SHADED AREAS INDICATE (TRIAL OPERATIONAL) DIFFERENCES
WIND ARROWS INDICATE VECTOR DIFFERENCES



→ REPRESENTS 2 M/S

FIGURE 3.7



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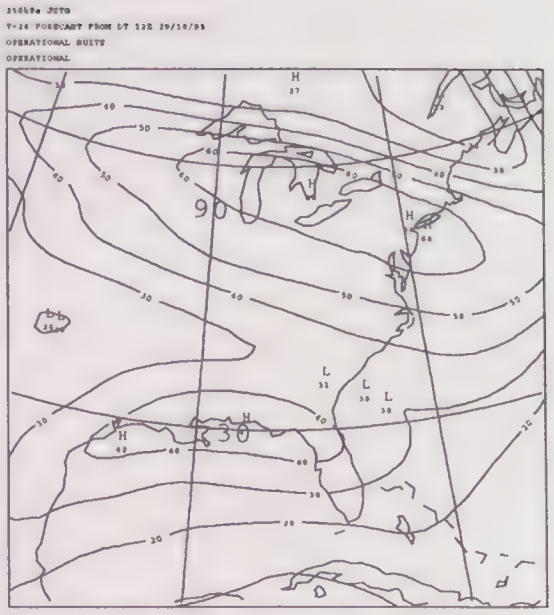

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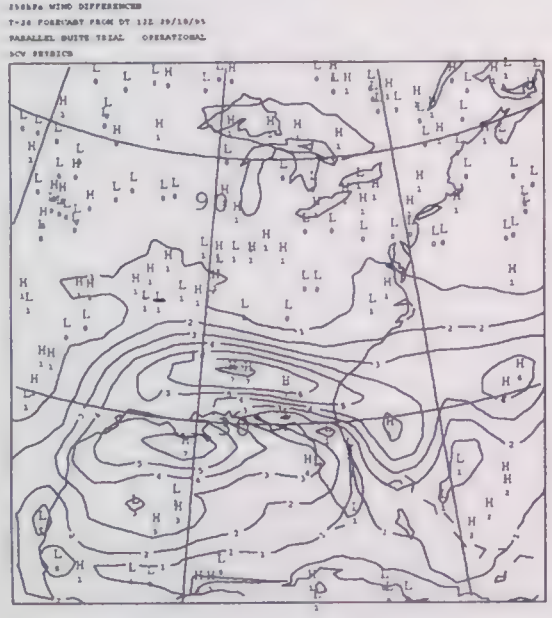
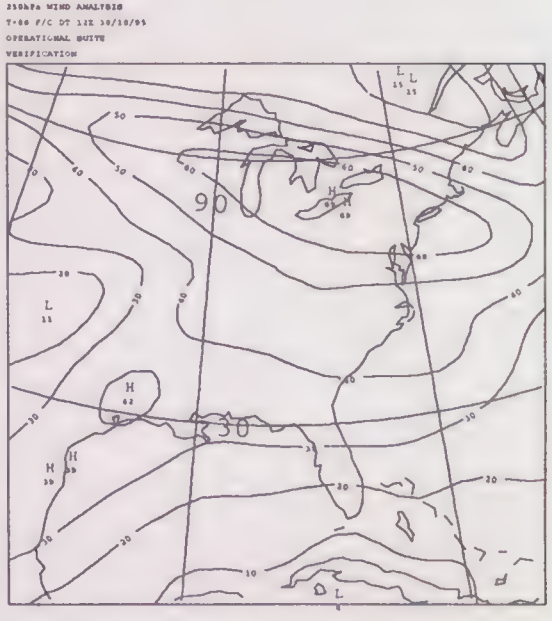
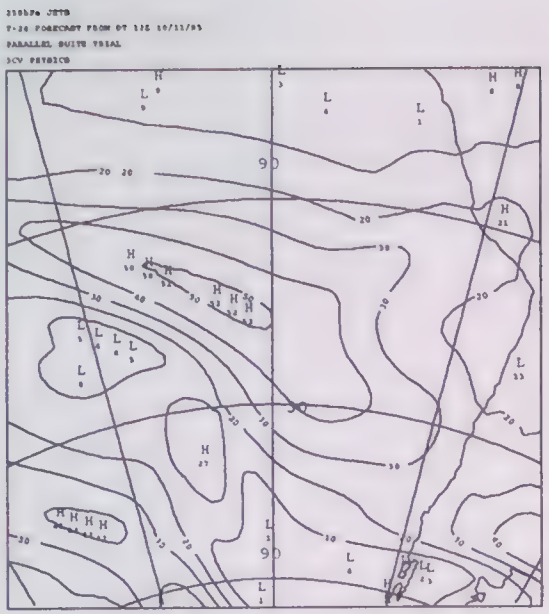


c



d

FIGURE 3.8



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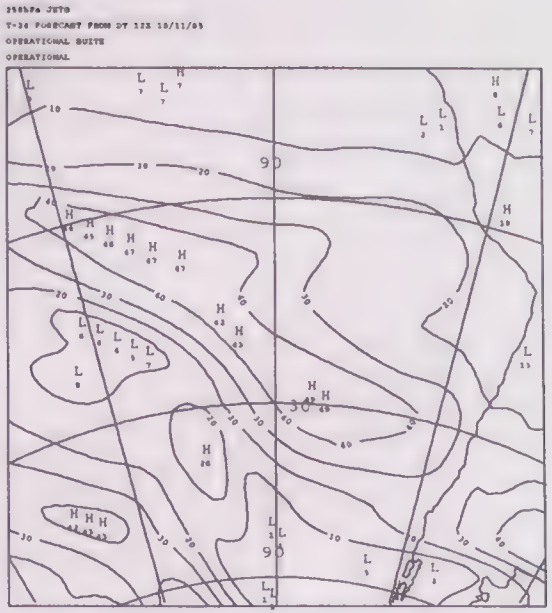

b

c

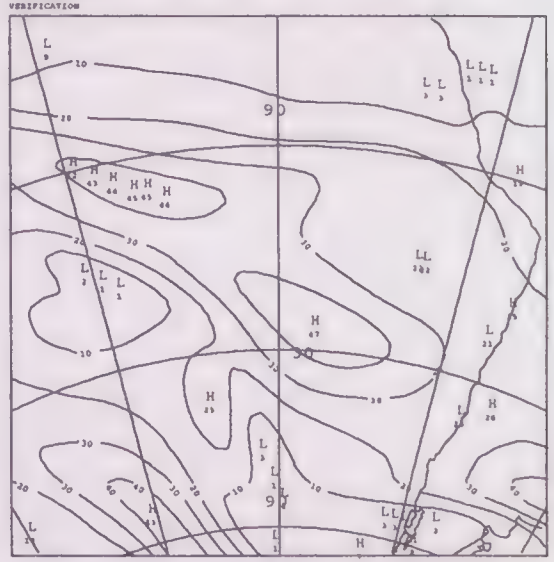

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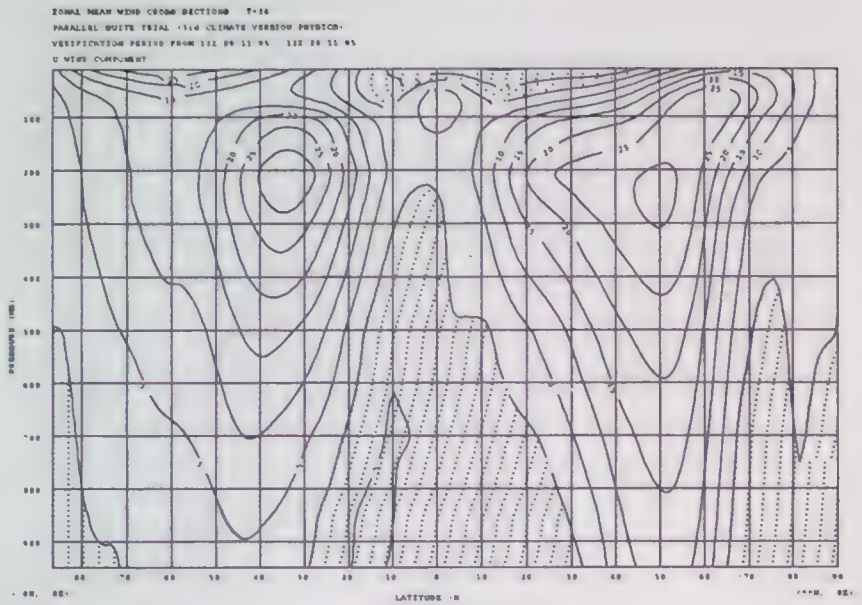
FIGURE 3.9



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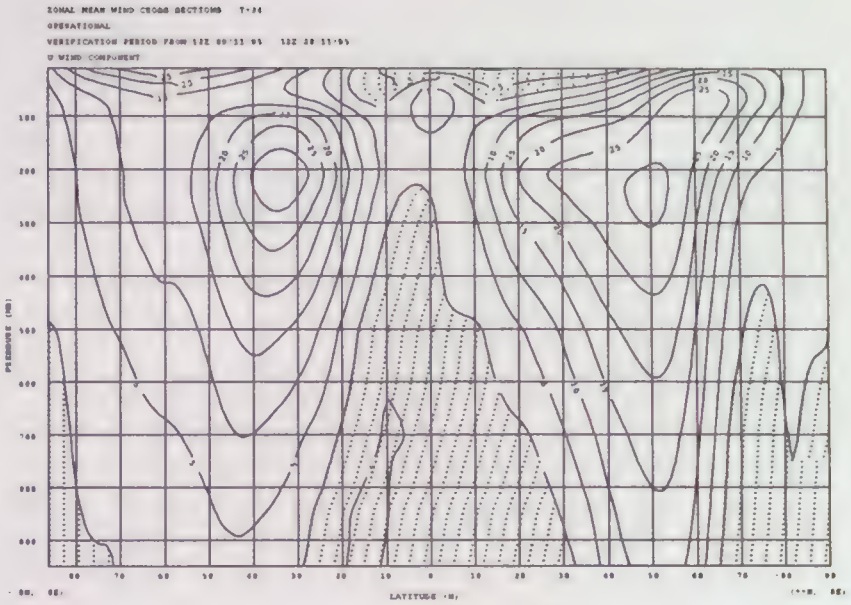

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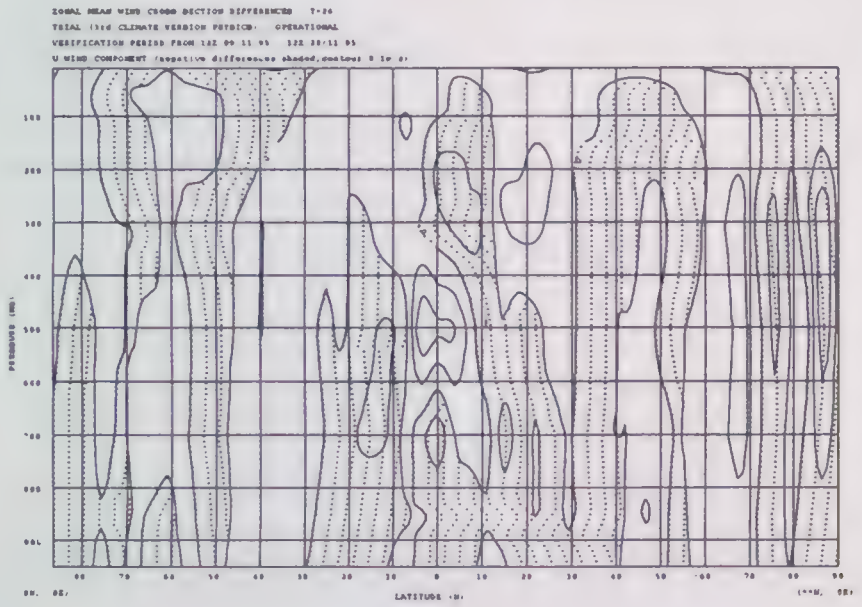

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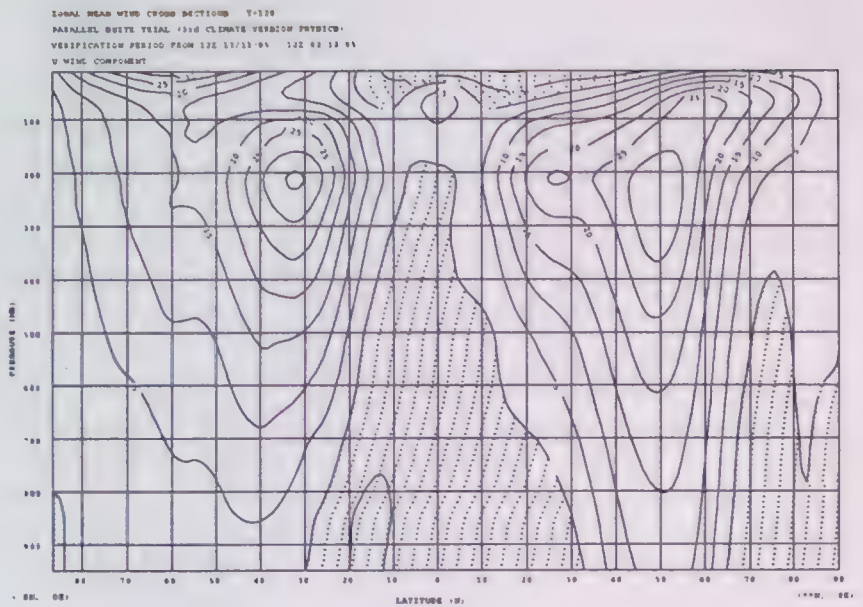
FIGURE 3.10



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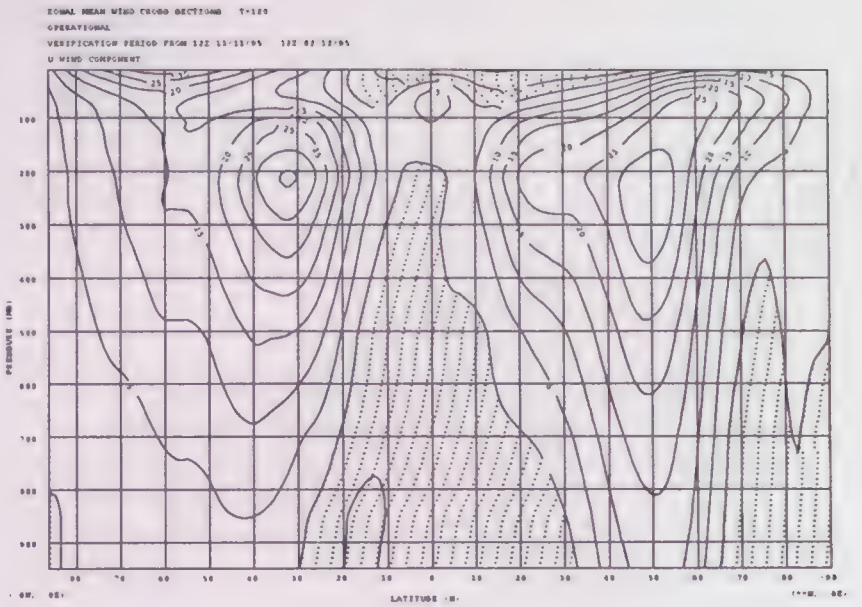

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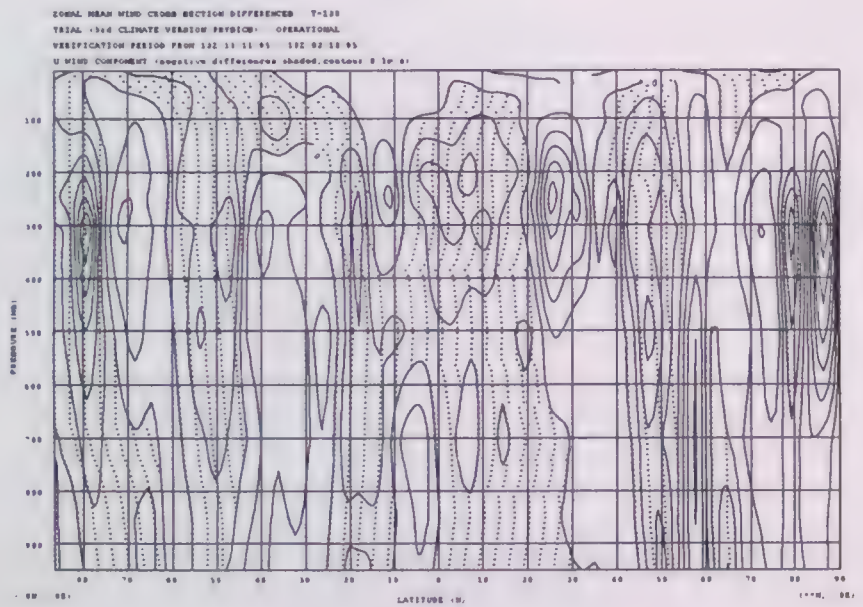

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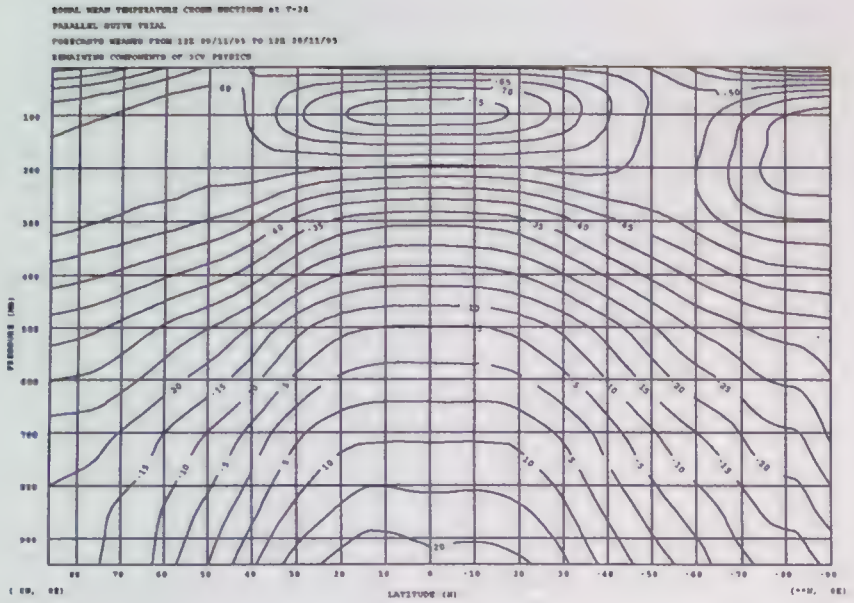
FIGURE 3.11



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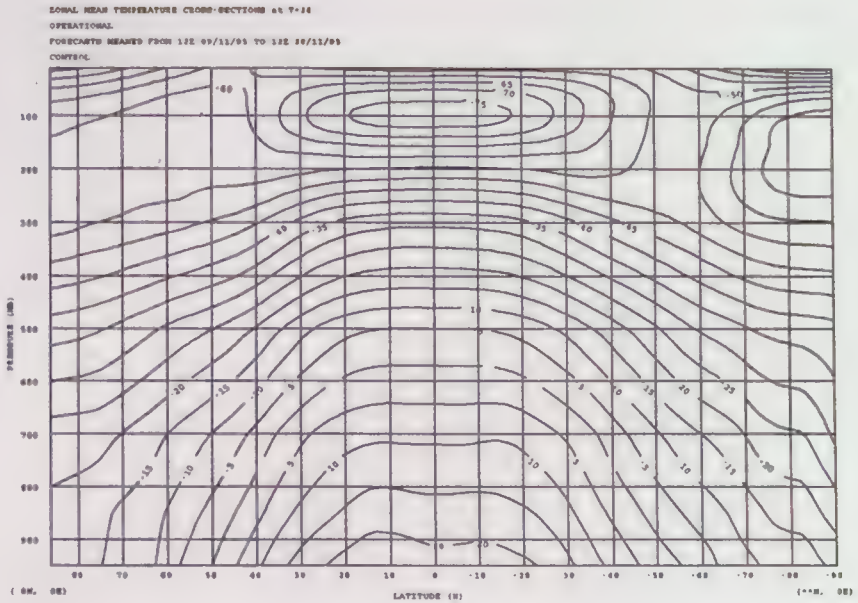

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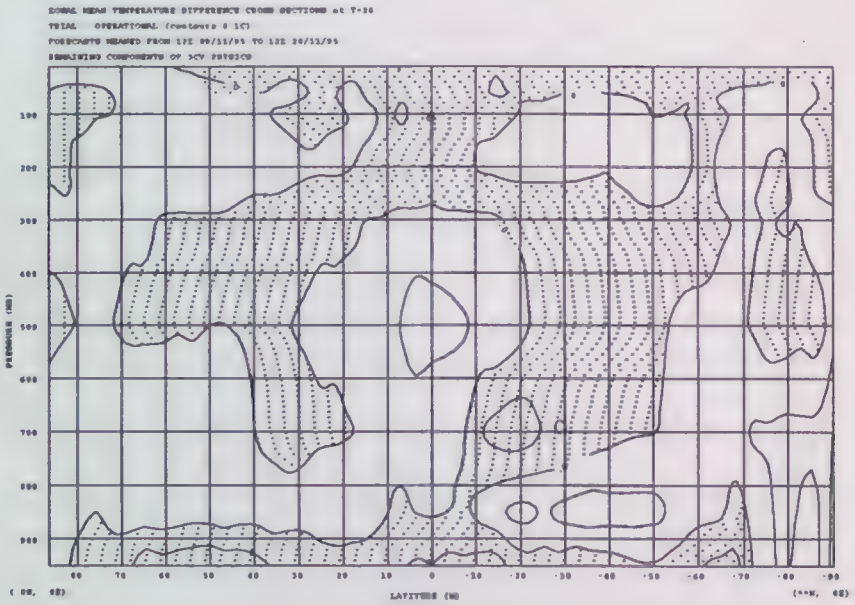
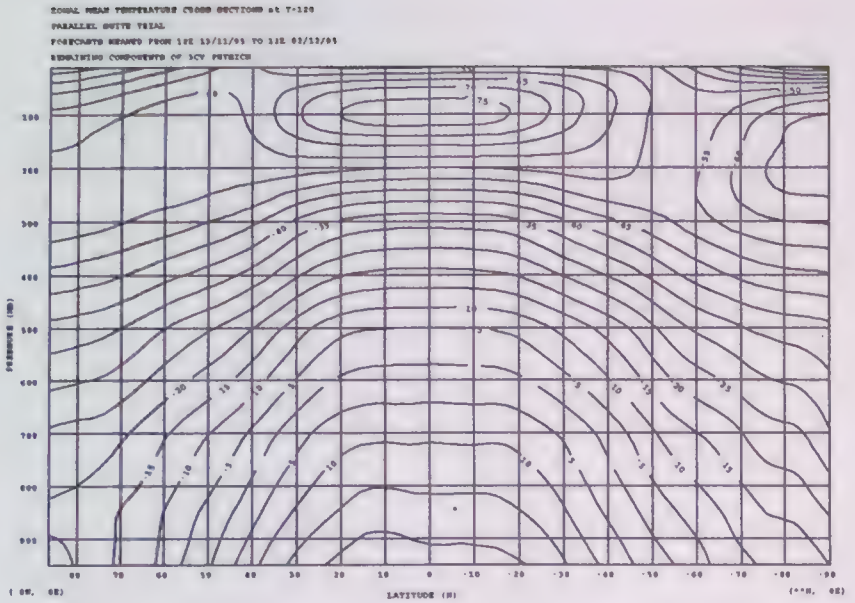


c

FIGURE 3.12



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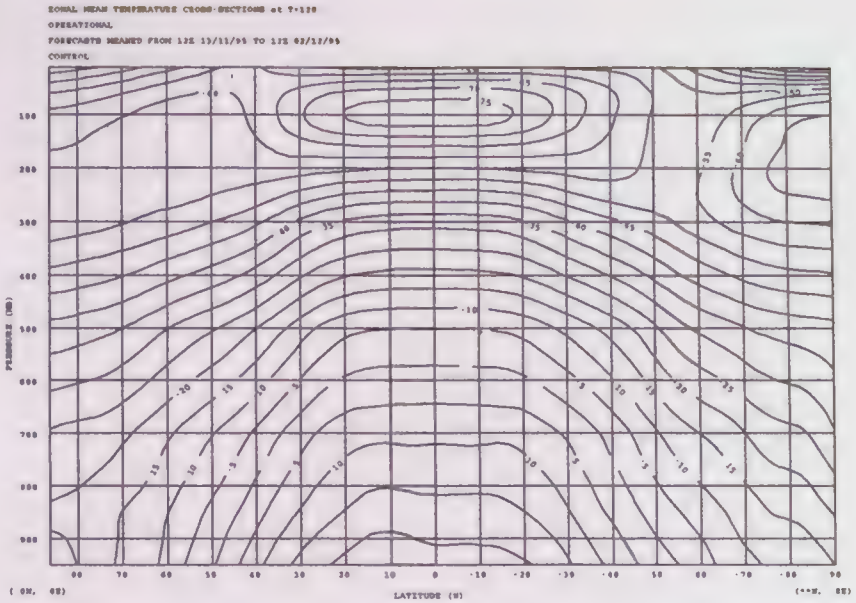

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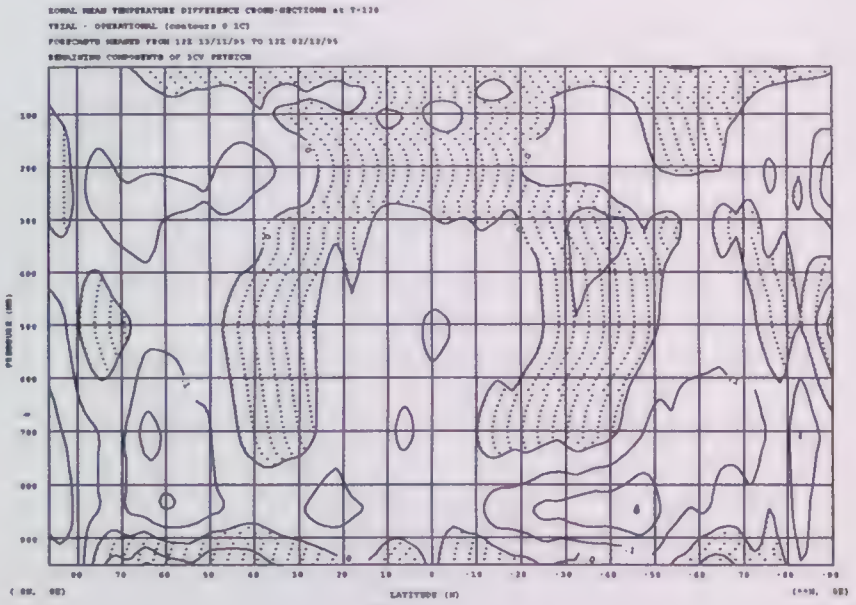
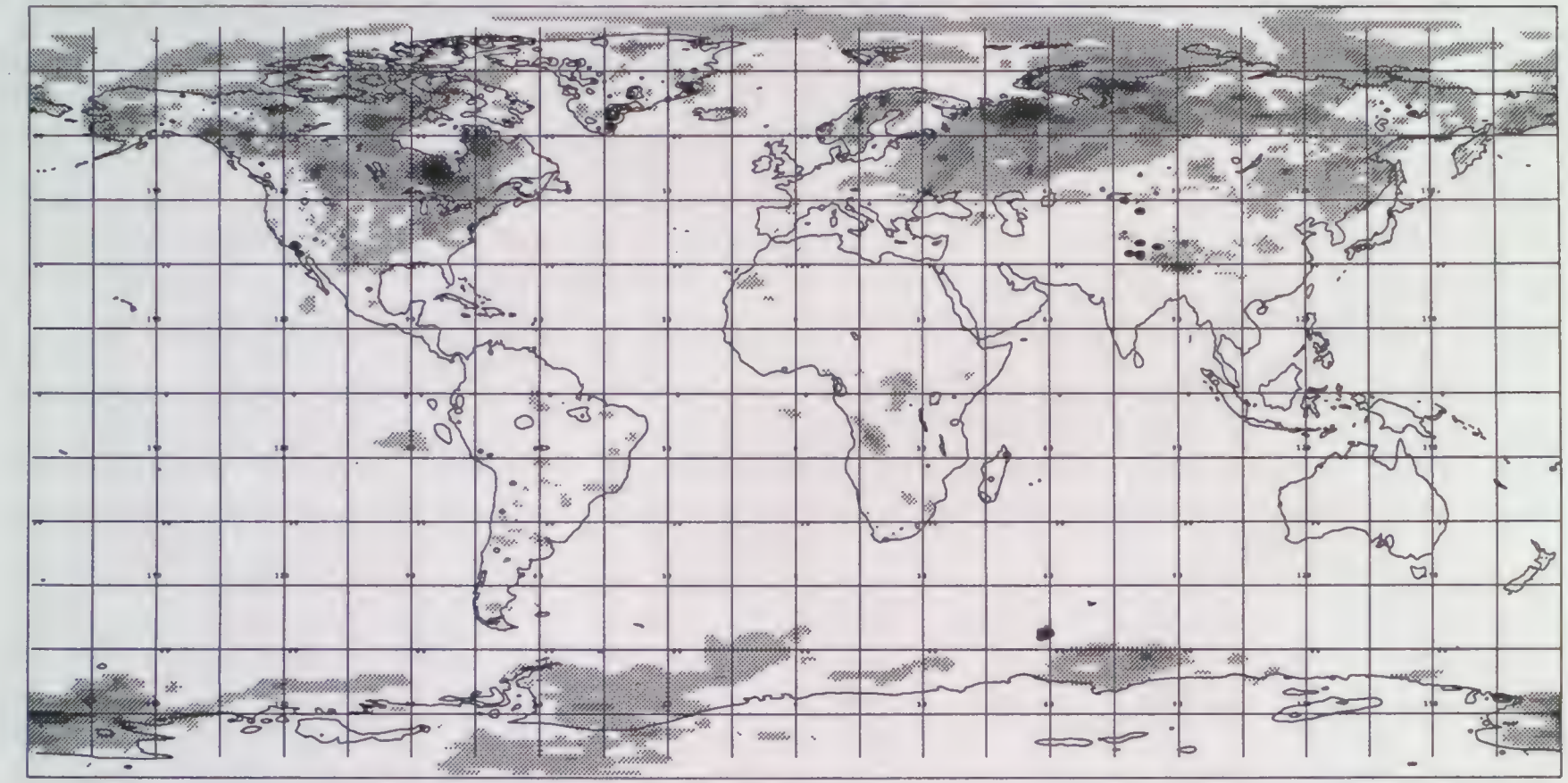


c

FIGURE 3.13

1.5M TEMPERATURE DIFFERENCES AT T+120(negative differences shaded)
T+120 FORECASTS MEANED FROM DT 12Z 08/11/95 to DT 12Z 27/11/95
TRIAL - OPERATIONAL
TRIAL (COMPONENTS OF 3CV PHYSICS)



-3.0 -2.5 -2.0 -1.5 -1.0 -.5 .0

FIGURE 3.14

MEAN LOW CLOUD DIFFERENCES T+120
PARALLEL SUITE TRIAL (COMPONENTS OF 3CV PHYSICS) - OPERATIONAL
FORECASTS MEANED OVER PERIOD FROM DT 12Z 08/11/95 TO 12Z 27/11/95
shaded areas indicate increase in low cloud

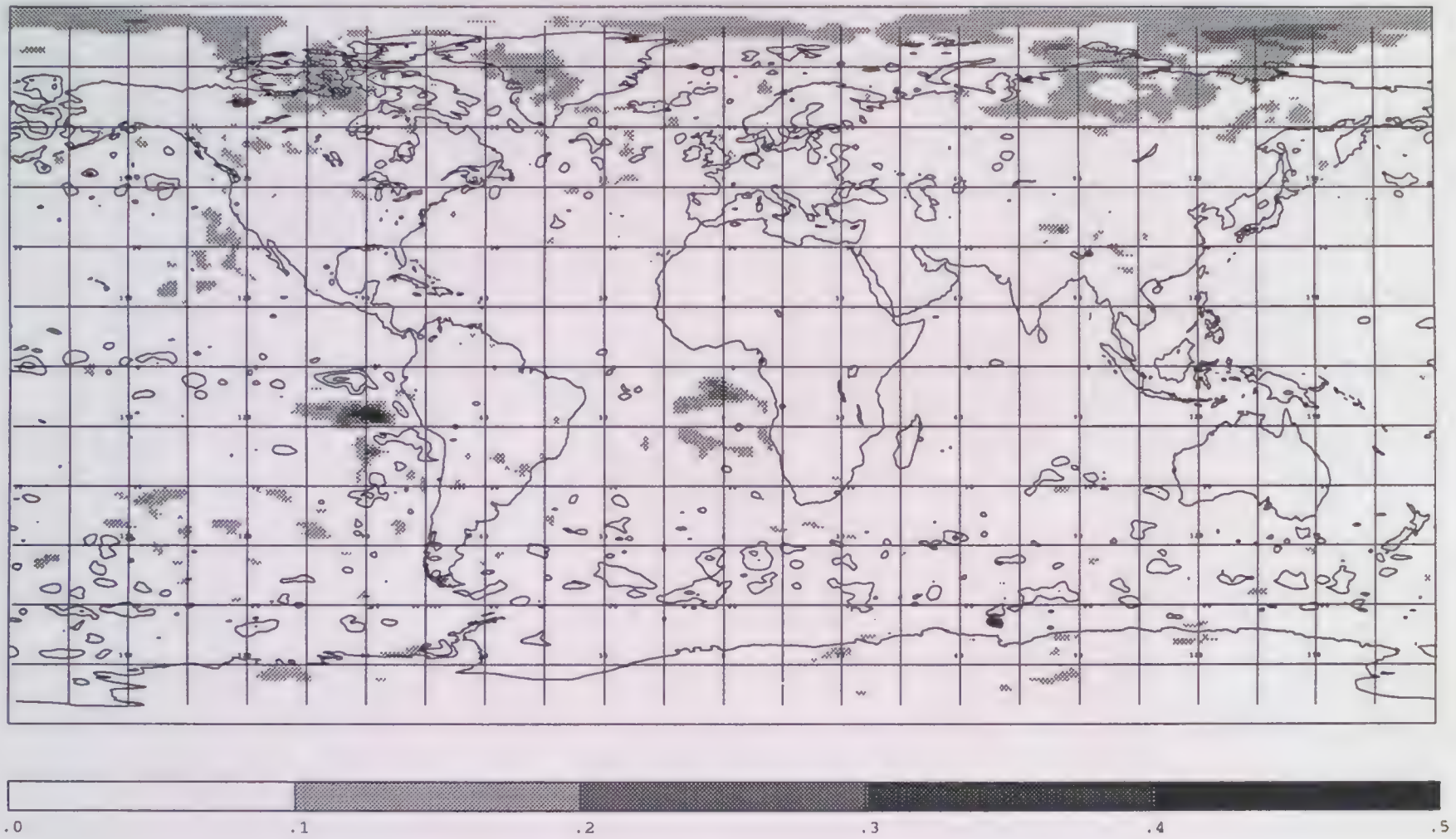


FIGURE 3.15

MEAN MEDIUM CLOUD DIFFERENCES T+120
PARALLEL SUITE TRIAL (COMPONENTS OF 3CV PHYSICS) - OPERATIONAL
FORECASTS MEANED OVER PERIOD FROM DT 12Z 08/11/95 TO 12Z 27/11/95
shaded areas indicate decrease in medium cloud

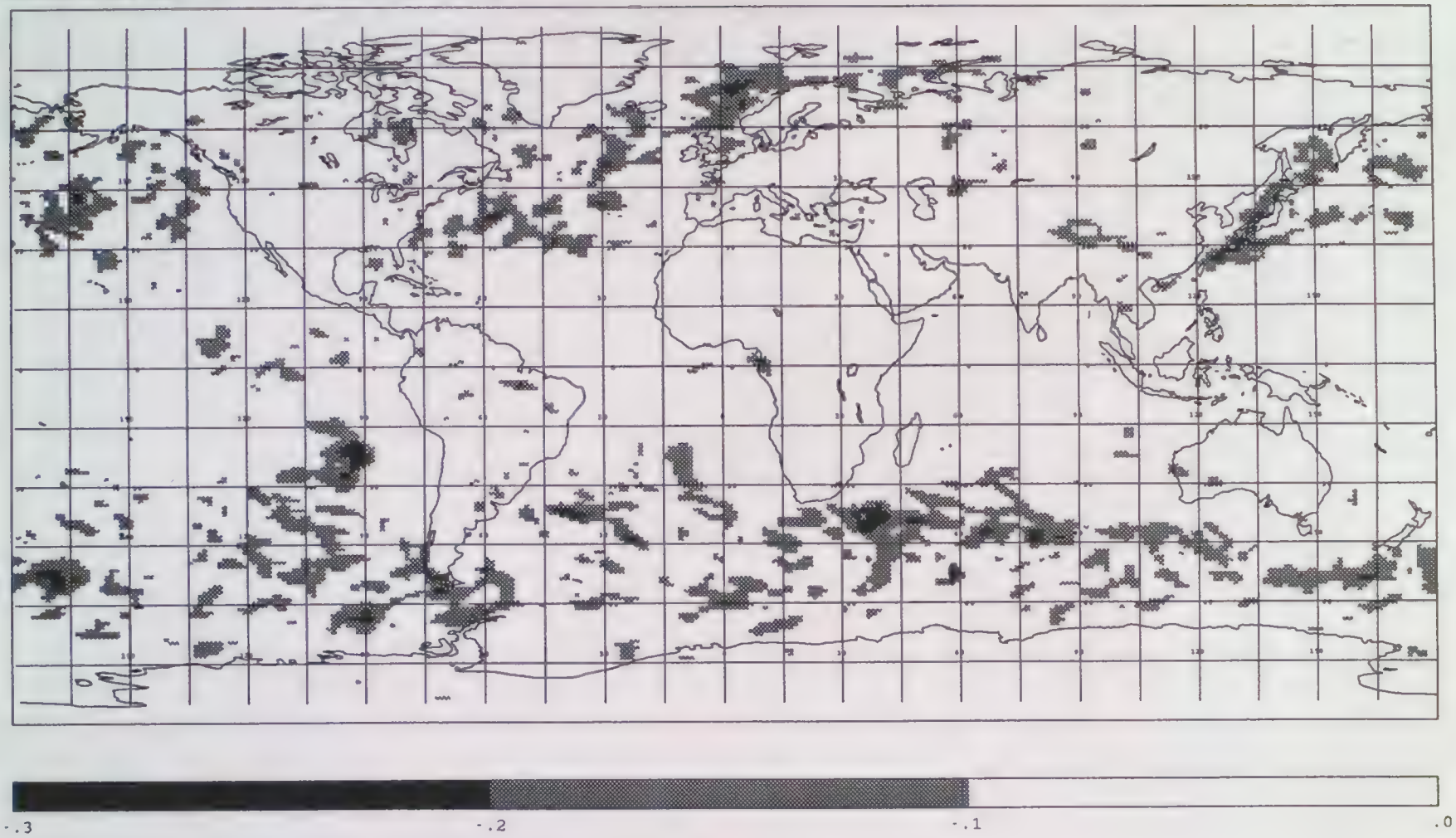


FIGURE 3.16

MEAN HIGH CLOUD DIFFERENCES T+120

PARALLEL SUITE TRIAL (COMPONENTS OF 3CV PHYSICS) - OPERATIONAL

FORECASTS MEANED OVER PERIOD FROM DT 12Z 08/11/95 TO 12Z 27/11/95

shaded areas indicate decrease in high cloud

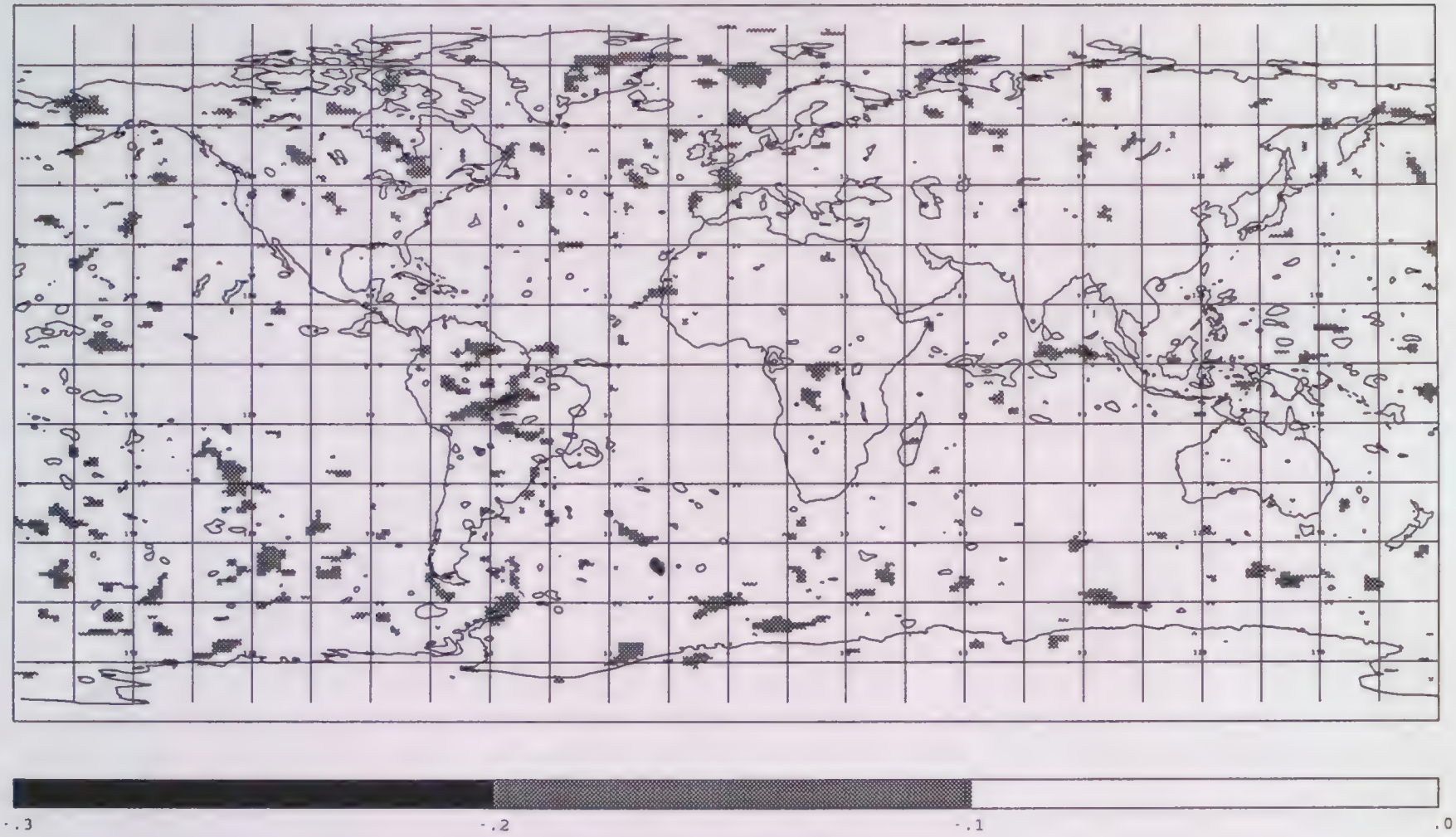
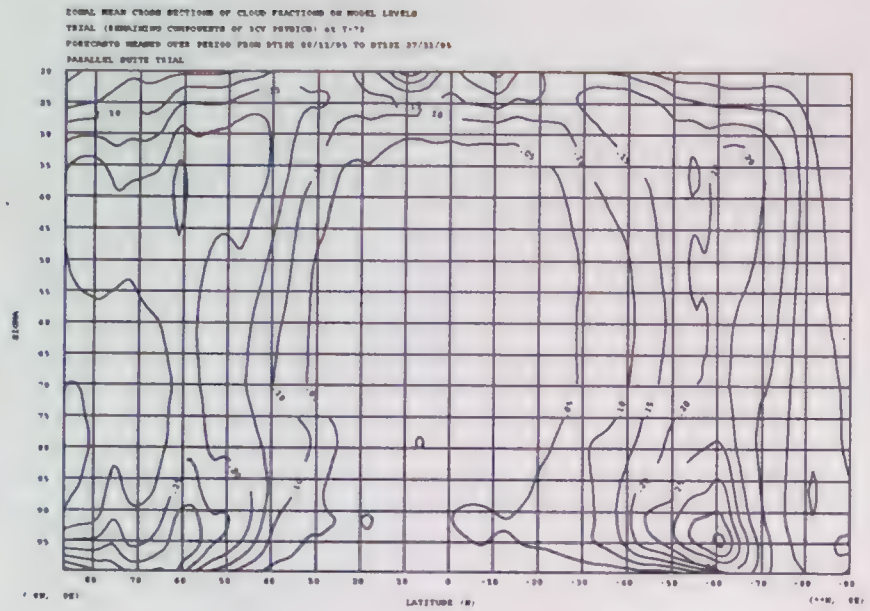


FIGURE 3.17



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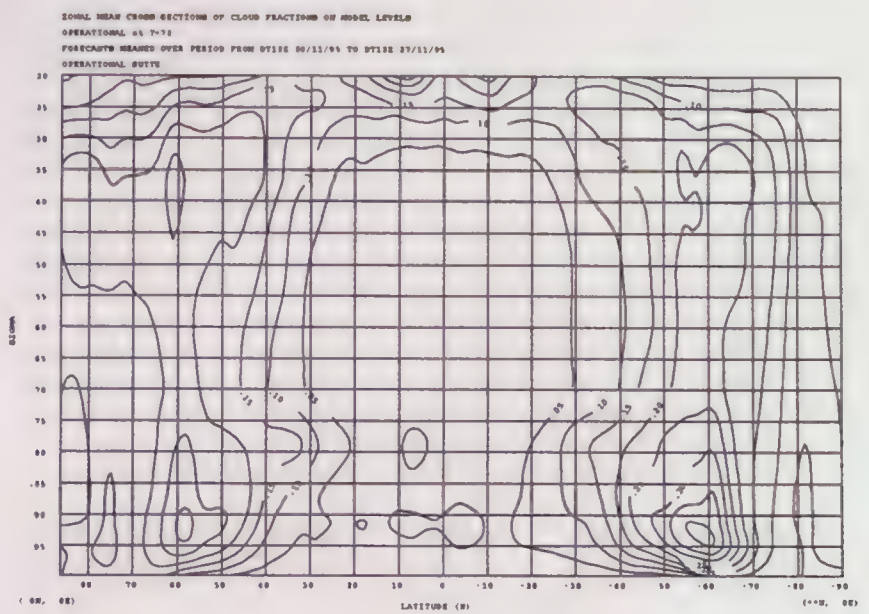
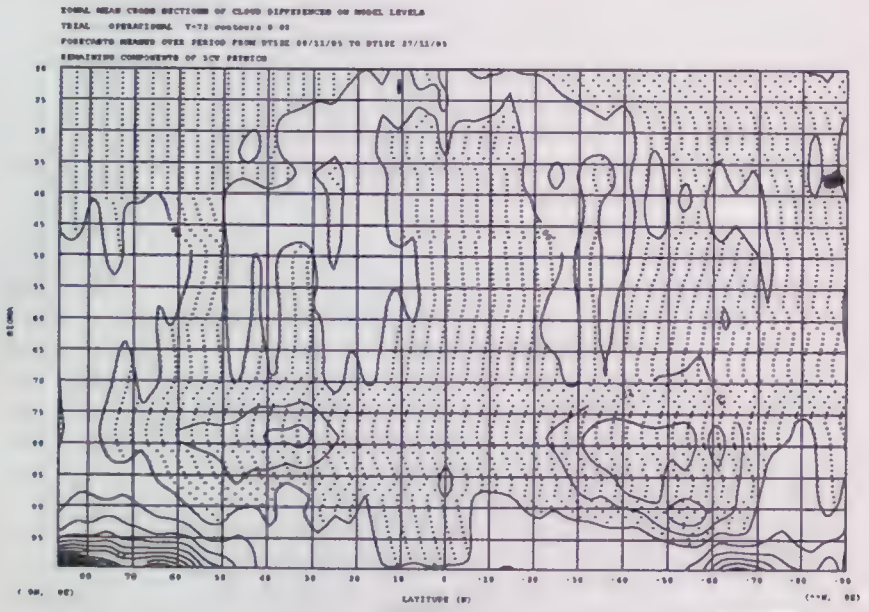
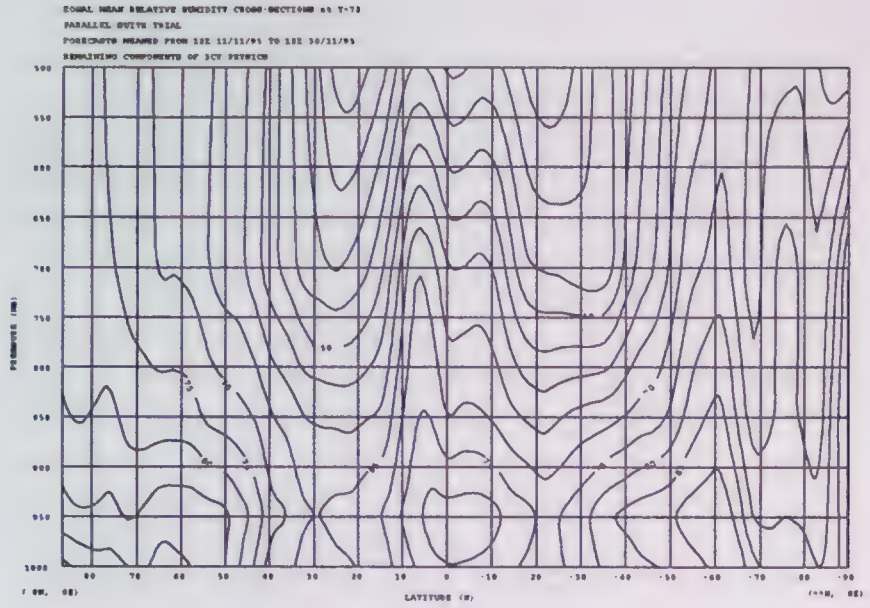


b



c

FIGURE 3.18



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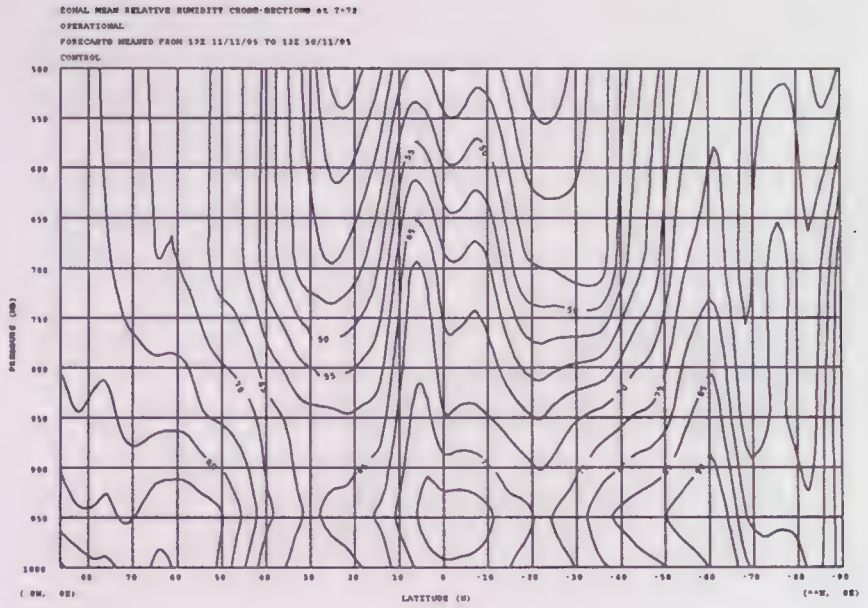

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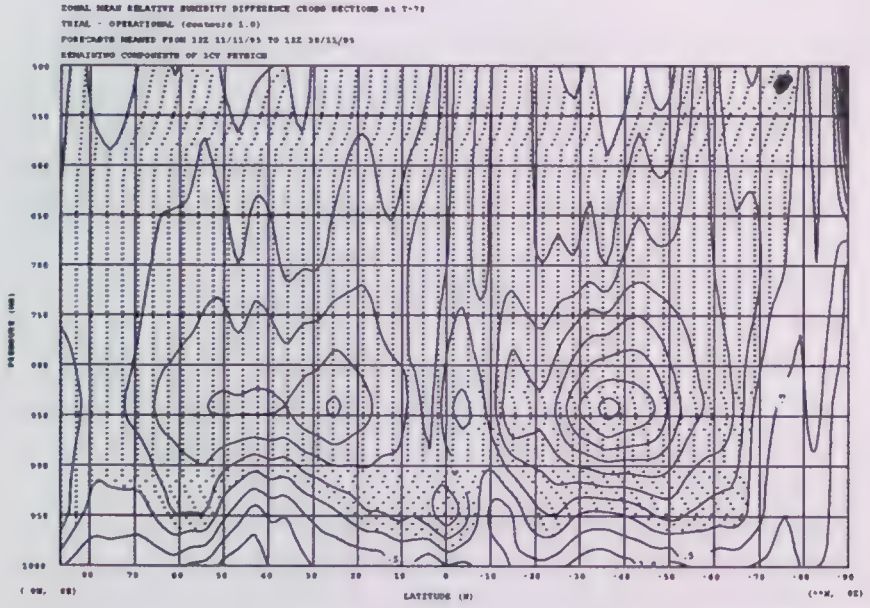


c

FIGURE 3.19

CONVECTIVE PRECIPITATION DIFFERENCES T+72 TRIAL - OPER
T+72 FORECASTS MEANED OVER PERIOD DT 12Z 08/11/95 TO DT 12Z 27/11/95
PARALLEL SUITE TRIAL (COMPONENTS OF 3CV PHYSICS)
trial increases in ppn shaded, decreases contoured

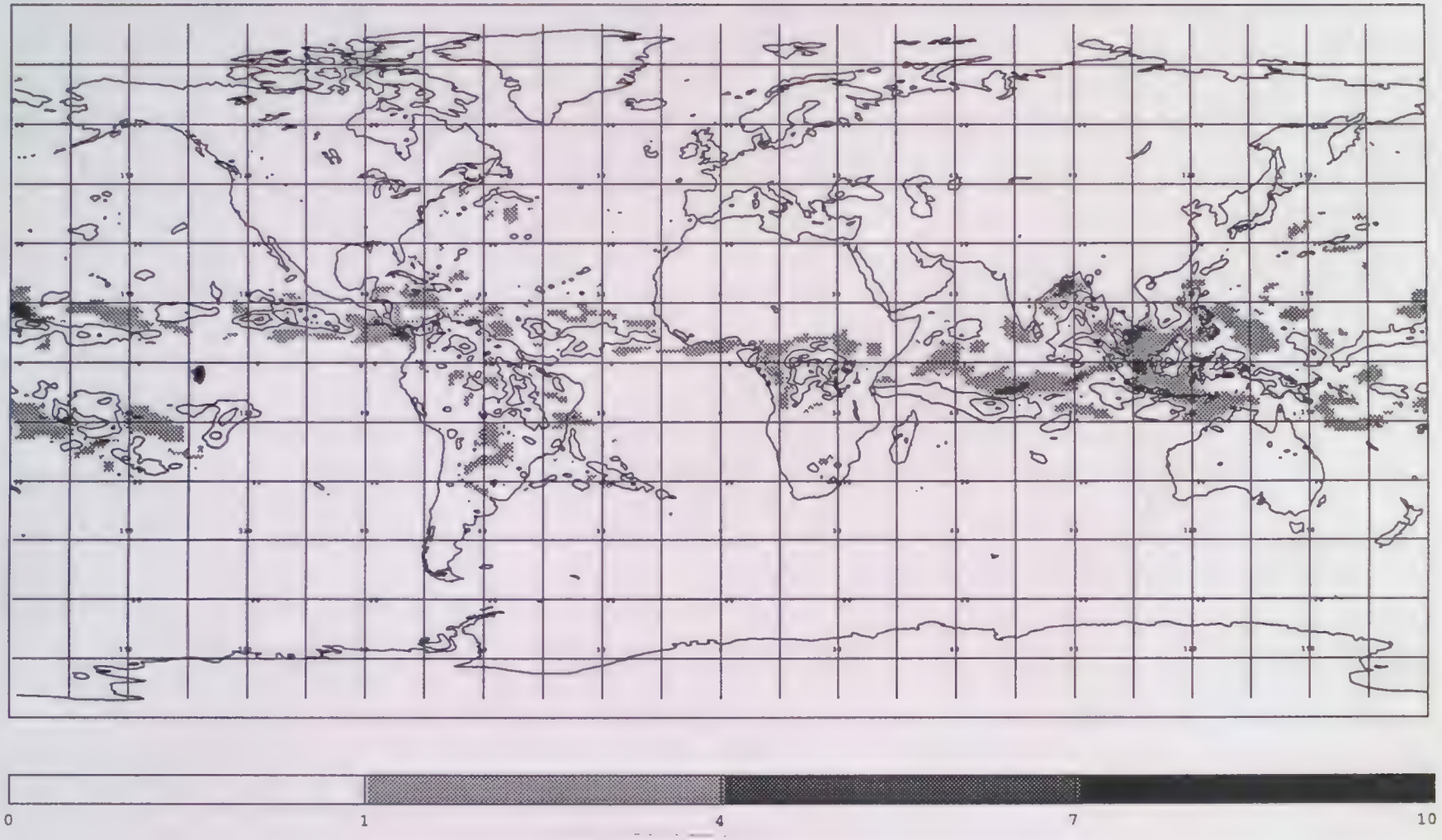


FIGURE 3.20

DYNAMIC PRECIPITATION DIFFERENCES T+72 TRIAL - OPER
T+72 FORECASTS MEANED OVER PERIOD DT 12Z 08/11/95 TO DT 12Z 27/11/95
PARALLEL SUITE TRIAL (COMPONENTS OF 3CV PHYSICS)
trial increases in ppn shaded, decreases contoured

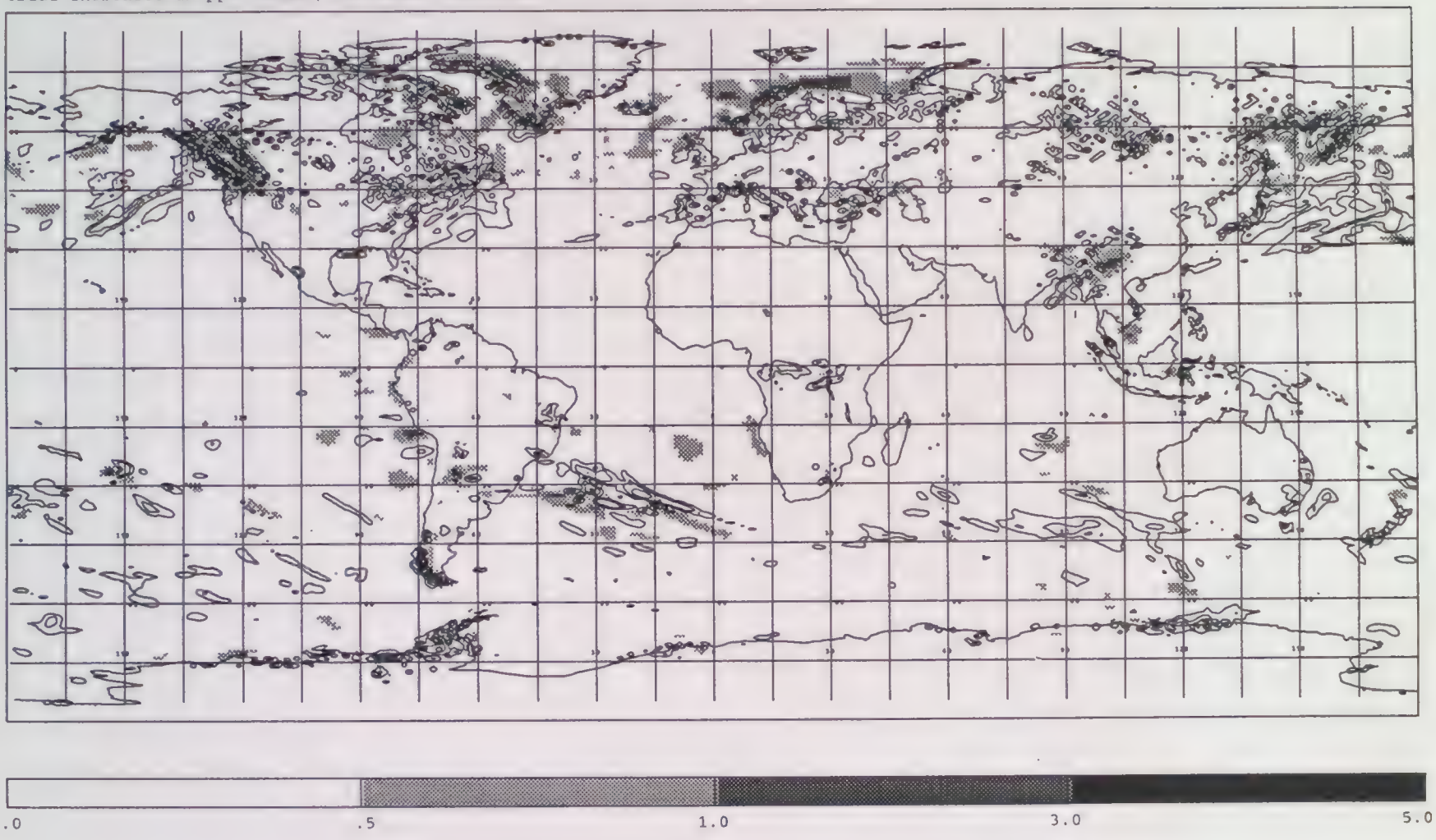


FIGURE 3.21

DYNAMIC PRECIPITATION DIFFERENCES T+72 TRIAL - OPER
T+72 FORECASTS MEANED OVER PERIOD DT 12Z 08/11/95 TO DT 12Z 27/11/95
PARALLEL SUITE TRIAL (COMPONENTS OF 3CV PHYSICS)
trial increases in ppn shaded, decreases contoured

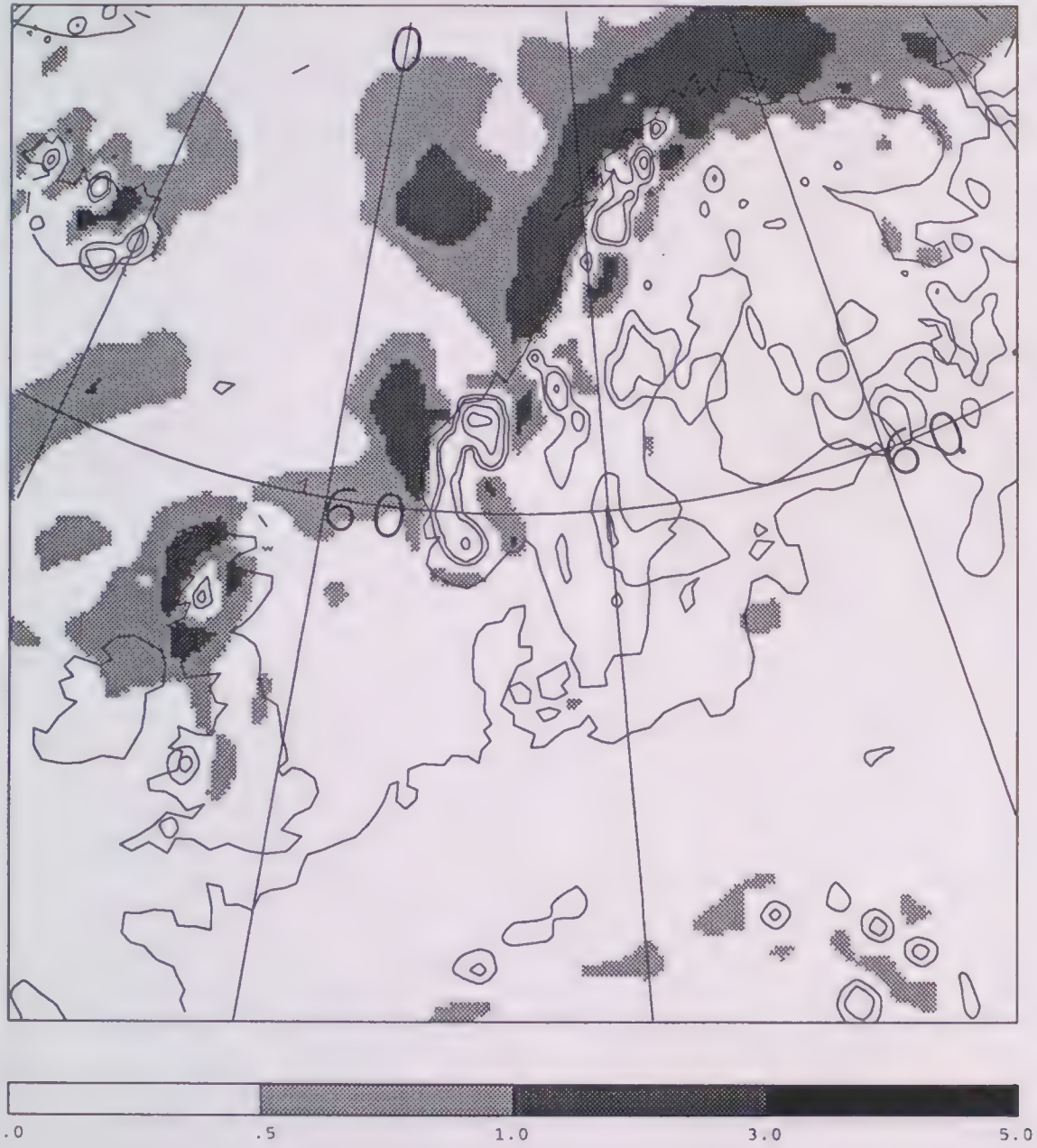


FIGURE 3.22

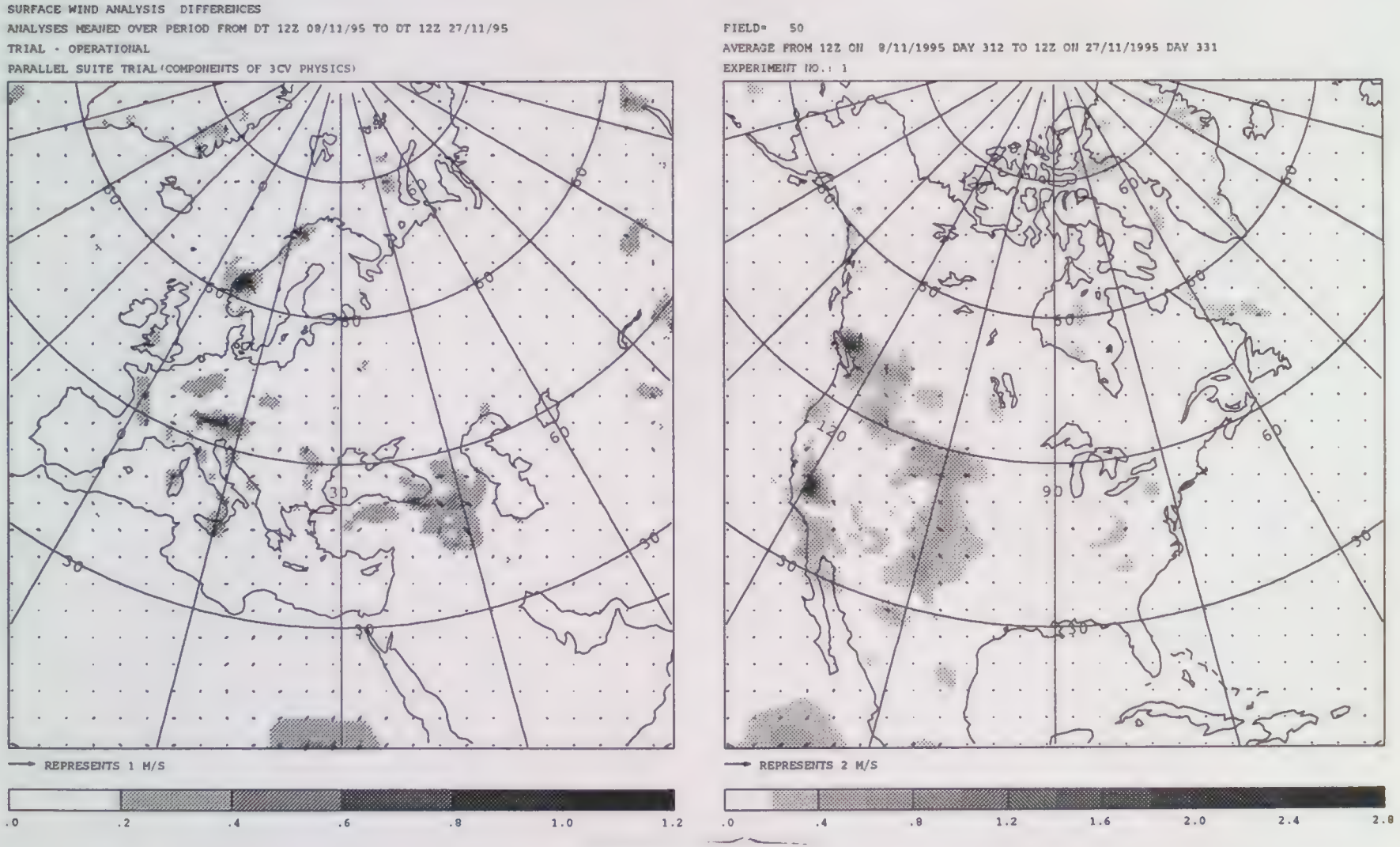
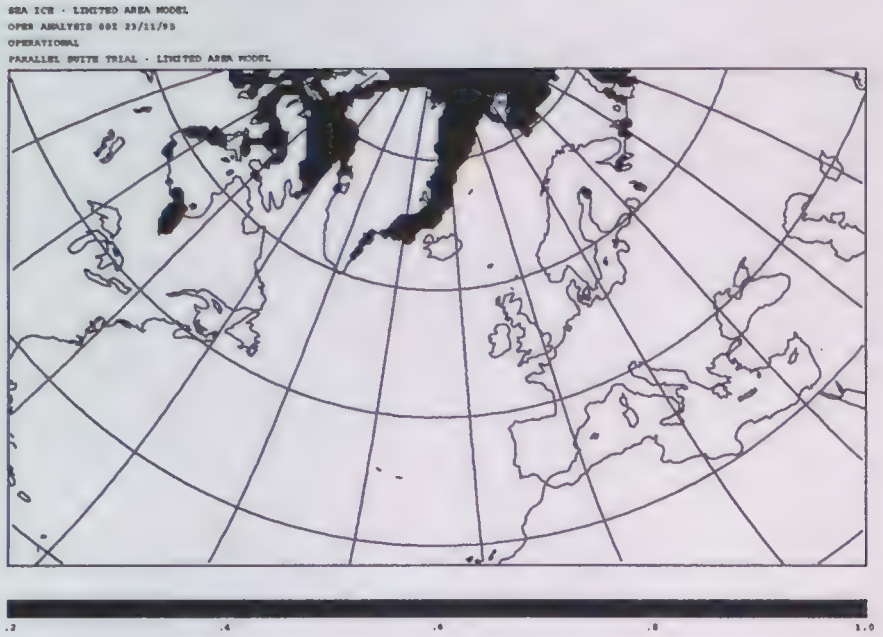
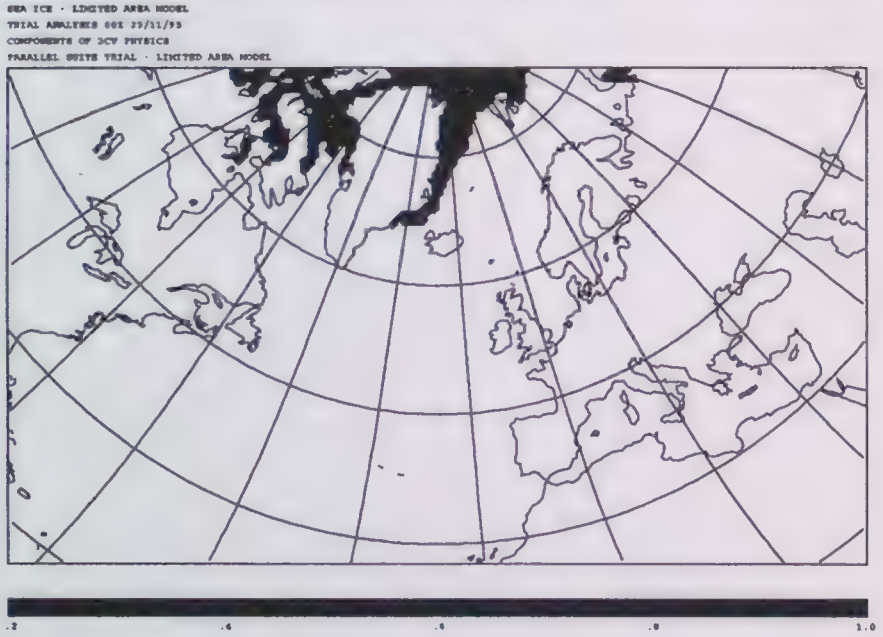

SURFACE WIND ANALYSIS DIFFERENCES
ANALYSES MEANED OVER PERIOD FROM DT 12Z 08/11/95 TO DT 12Z 27/11/95
TRIAL - OPERATIONAL
PARALLEL SUITE TRIAL(COMPONENTS OF 3CV PHYSICS)
FIELD= 50
AVERAGE FROM 12Z ON 8/11/1995 DAY 312 TO 12Z ON 27/11/1995 DAY 331
EXPERIMENT NO.: 1
30
60
90
120
REPRESENTS 1 M/S
REPRESENTS 2 M/S
.0 .2 .4 .6 .8 1.0 1.2
.0 .4 .8 1.2 1.6 2.0 2.4 2.8

FIGURE 3.23

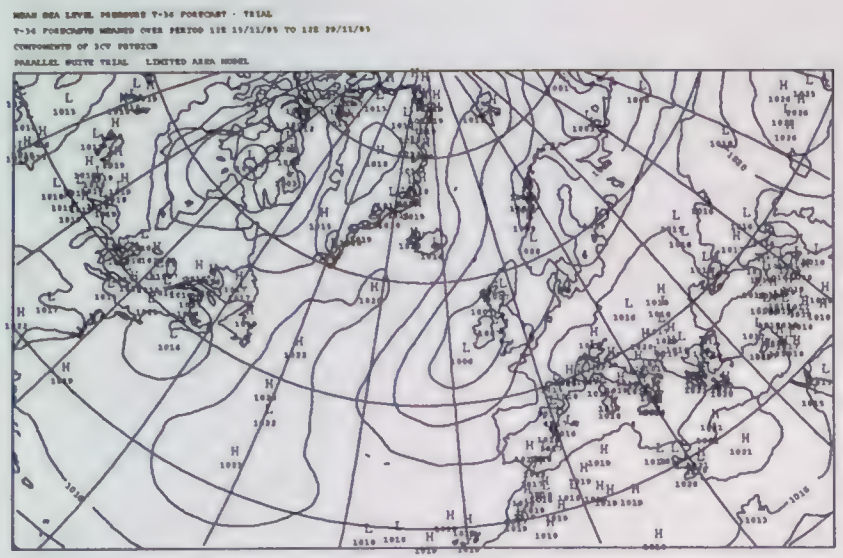

SEA ICE - LIMITED AREA MODEL
OPER ANALYSIS 00Z 23/11/99
OPERATIONAL
PARALLEL SUITE TRIAL - LIMITED AREA MODEL
.2
.4
.6
.8
1.0

a


SEA ICE - LIMITED AREA MODEL
TRIAL ANALYSIS 00Z 23/11/99
COMPONENTS OF 3CV PHYSICS
PARALLEL SUITE TRIAL - LIMITED AREA MODEL
.2
.4
.6
.8
1.0

b

FIGURE 4.1



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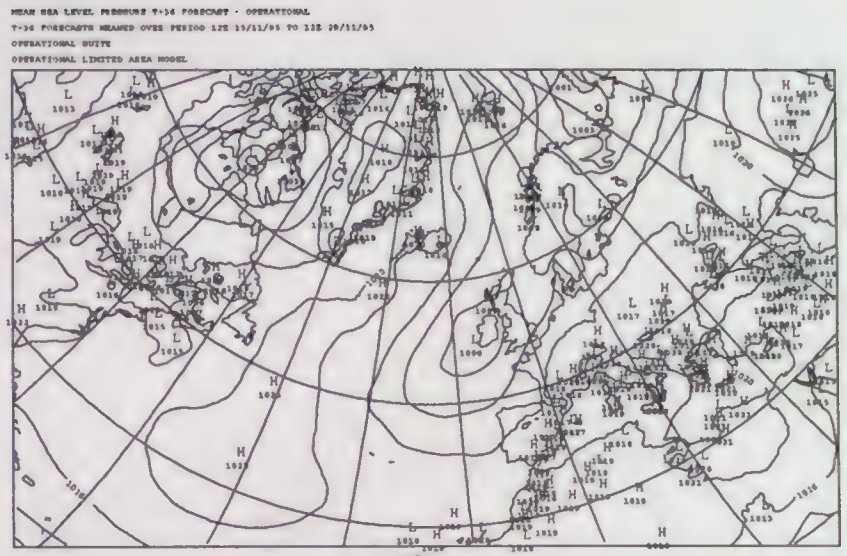

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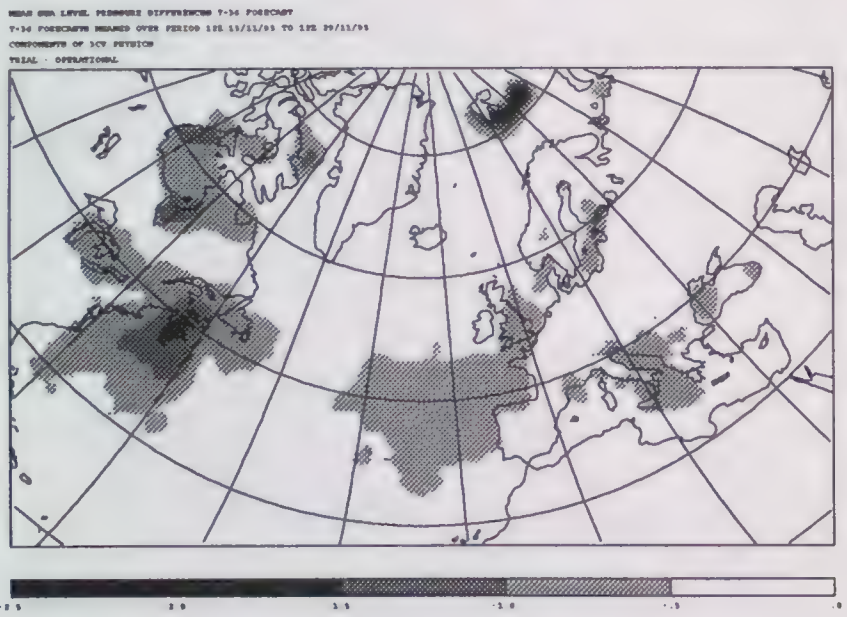
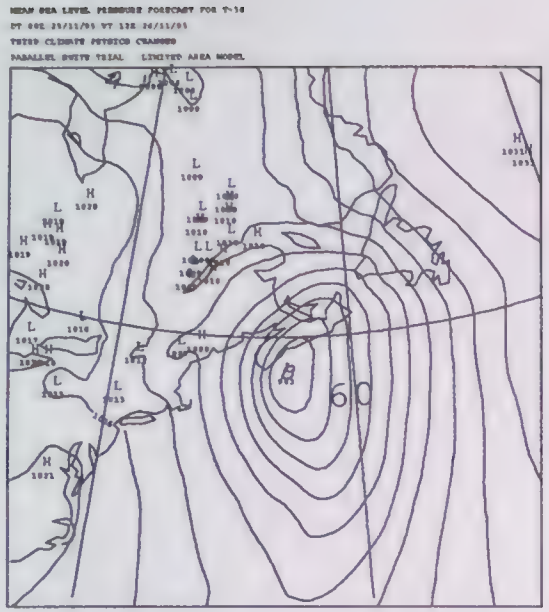


c

FIGURE 4.2



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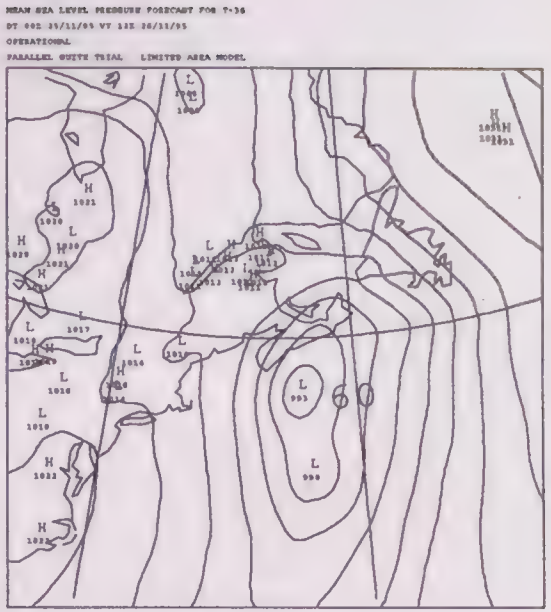

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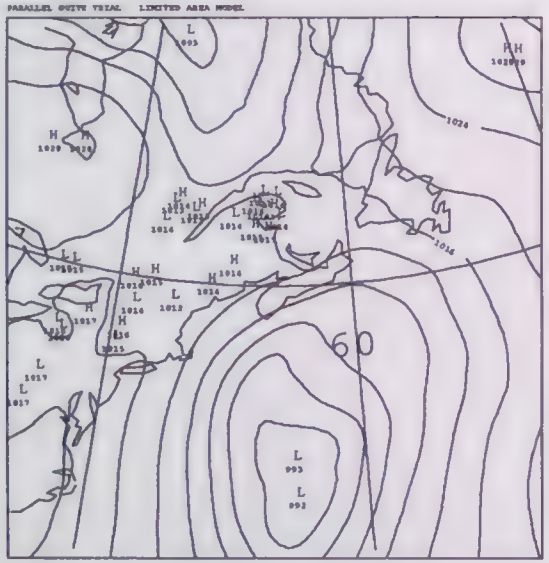

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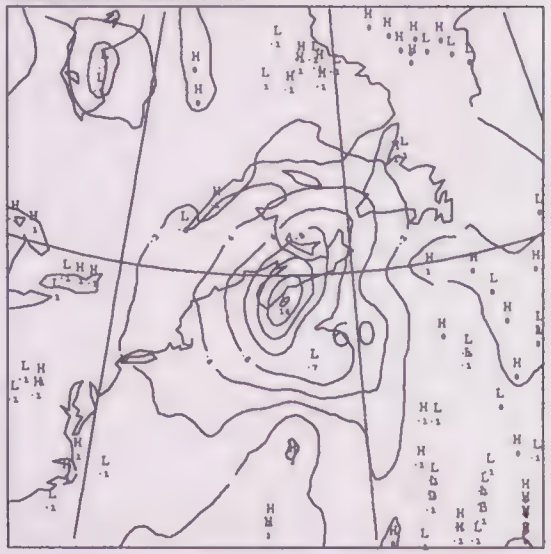
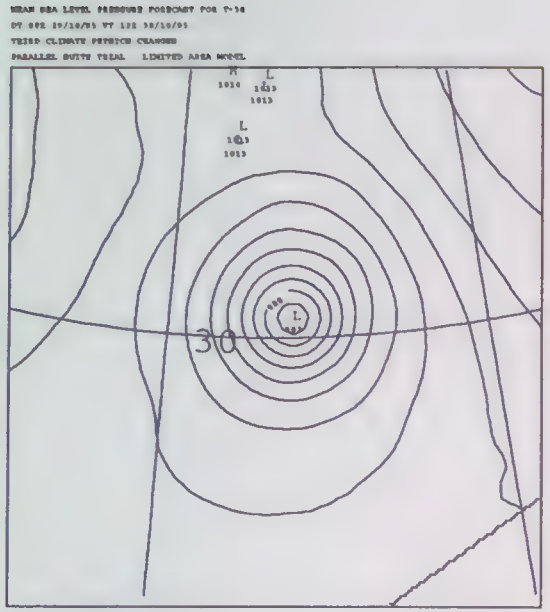


d

FIGURE 4.3



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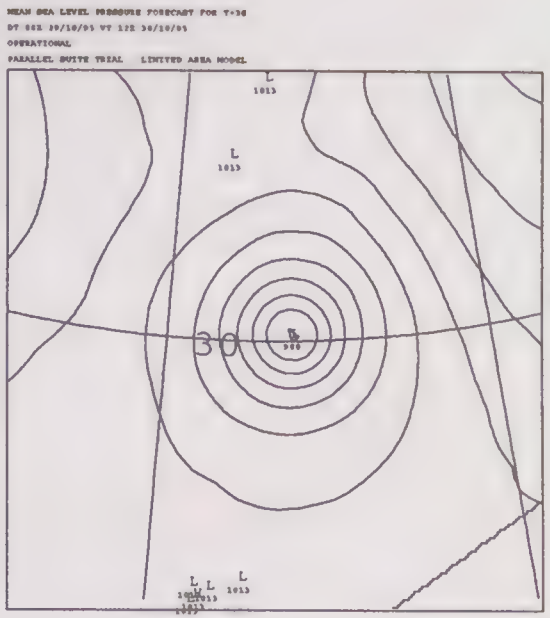

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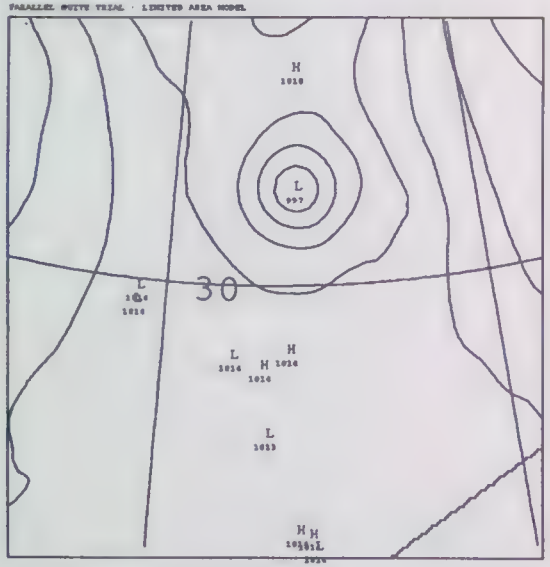

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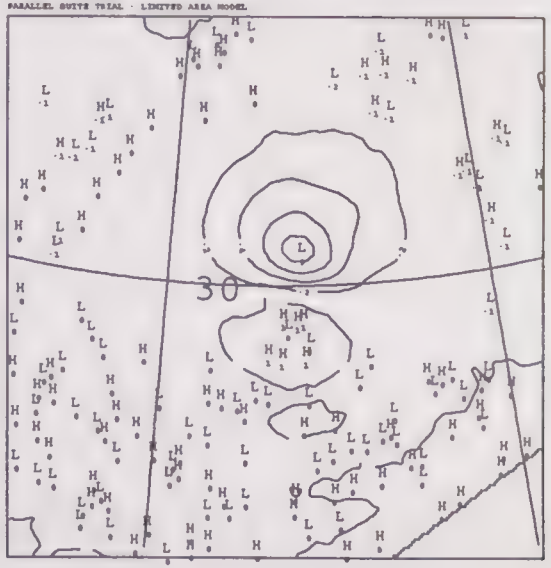
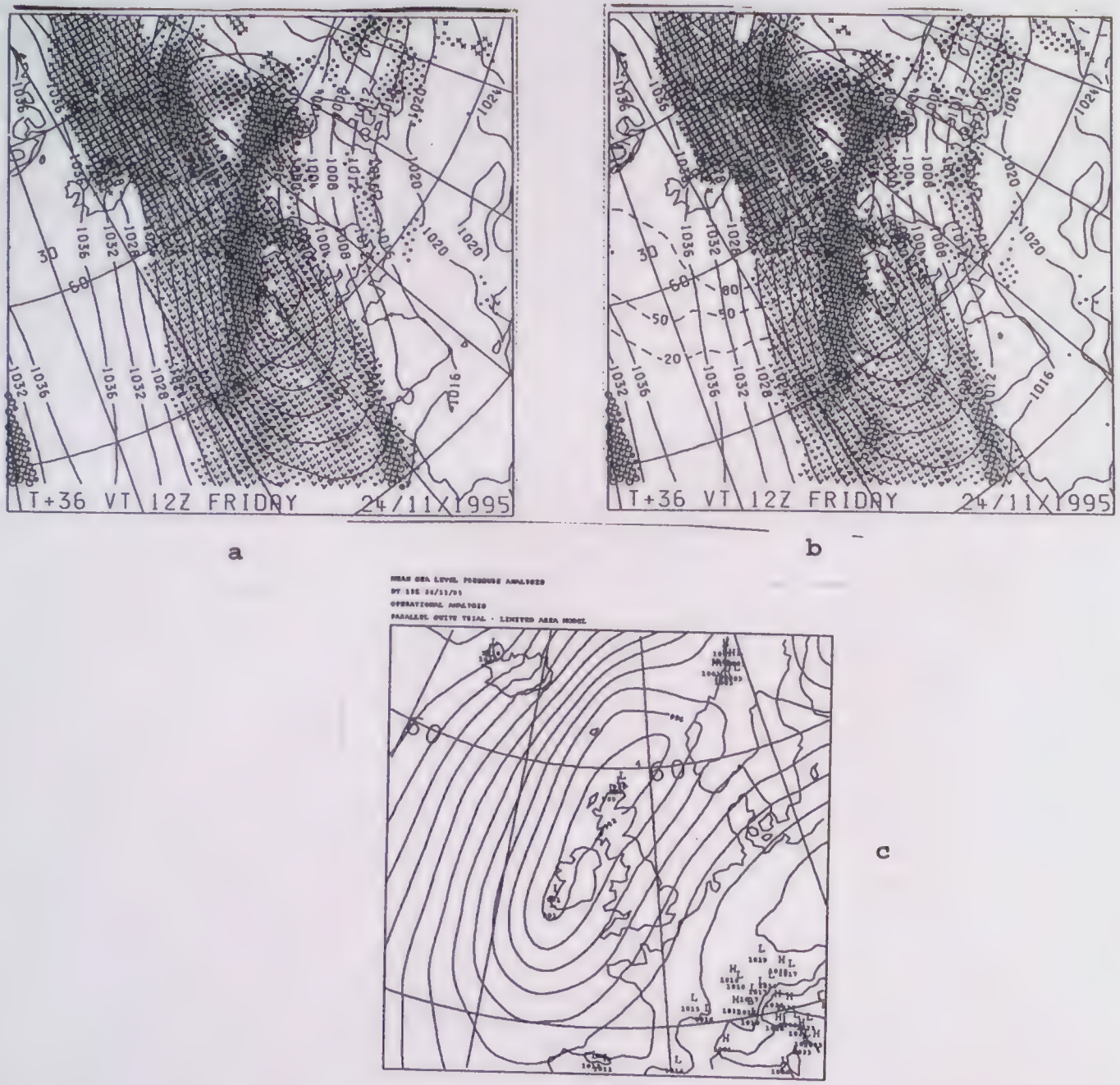


d

FIGURE 4.4



a

b

c

FIGURE 4.5

10M WIND ANALYSIS DIFFERENCES
10M WIND ANALYSES MEANED FROM 00Z 14/11/95 TO 00Z 28/11/95
PARALLEL SUITE TRIAL - OPERATIONAL
PARALLEL SUITE TRIAL (COMPONENTS OF THIRD CLIMATE PHYSICS)

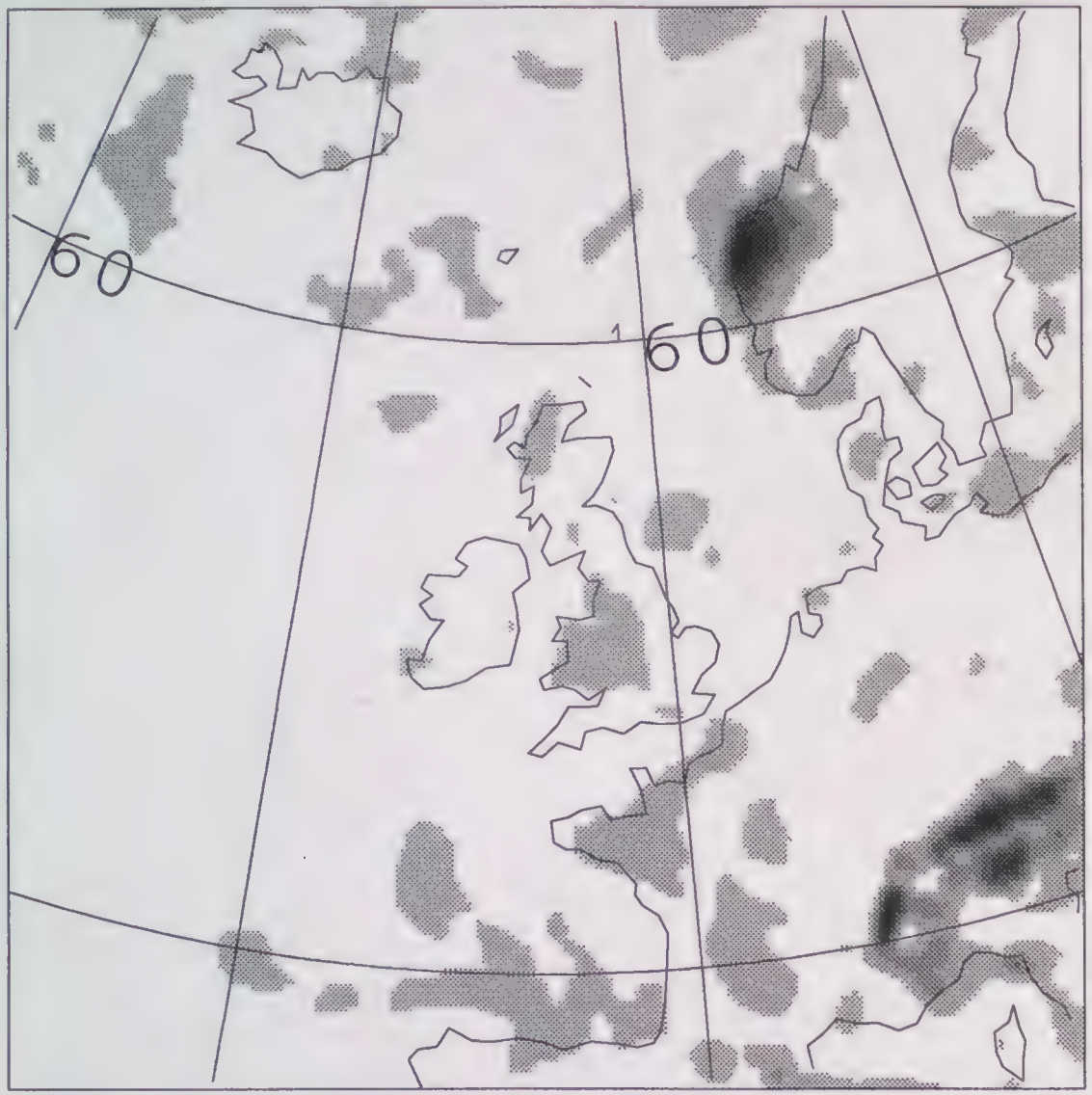
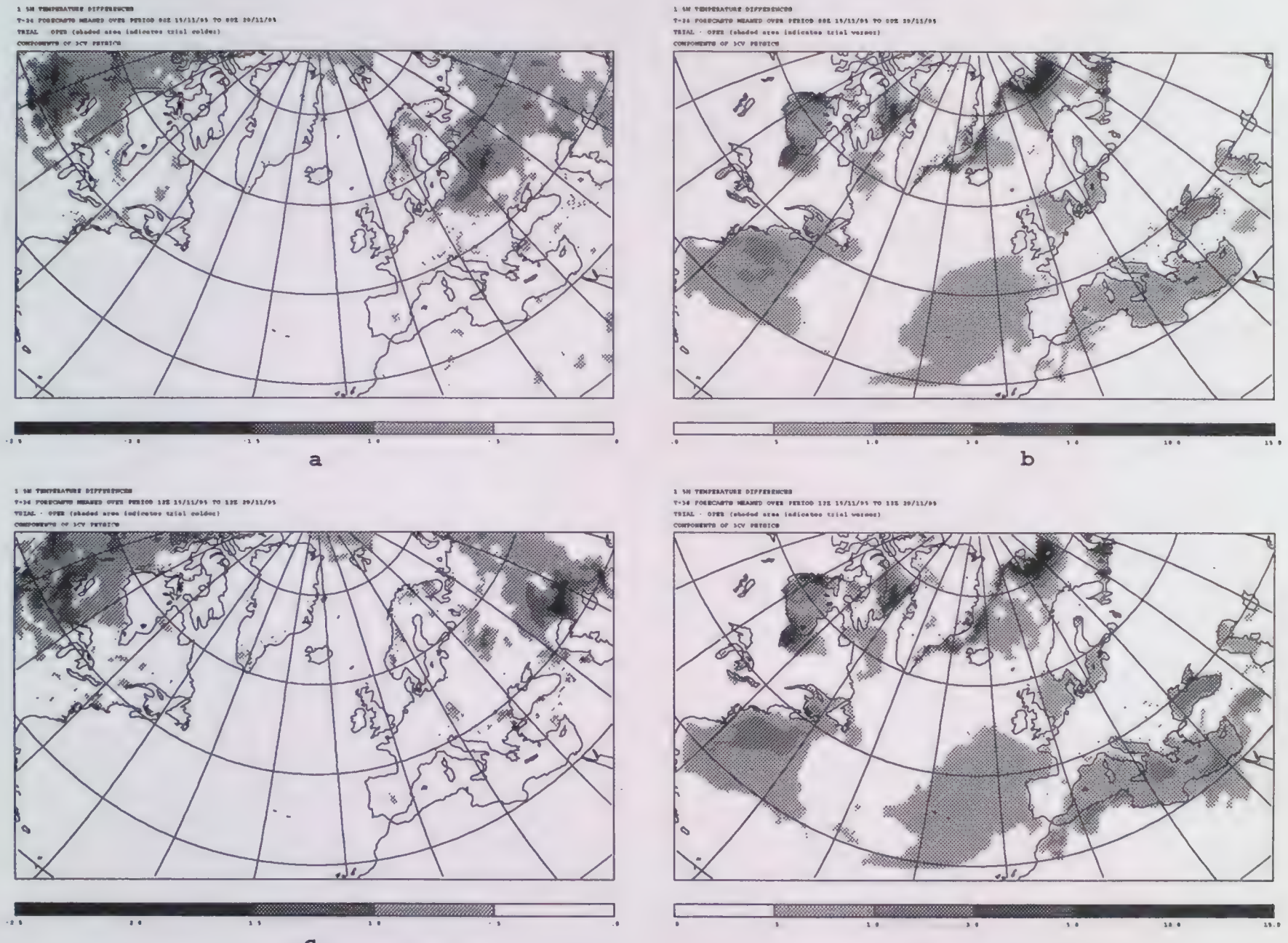


FIGURE 4.6



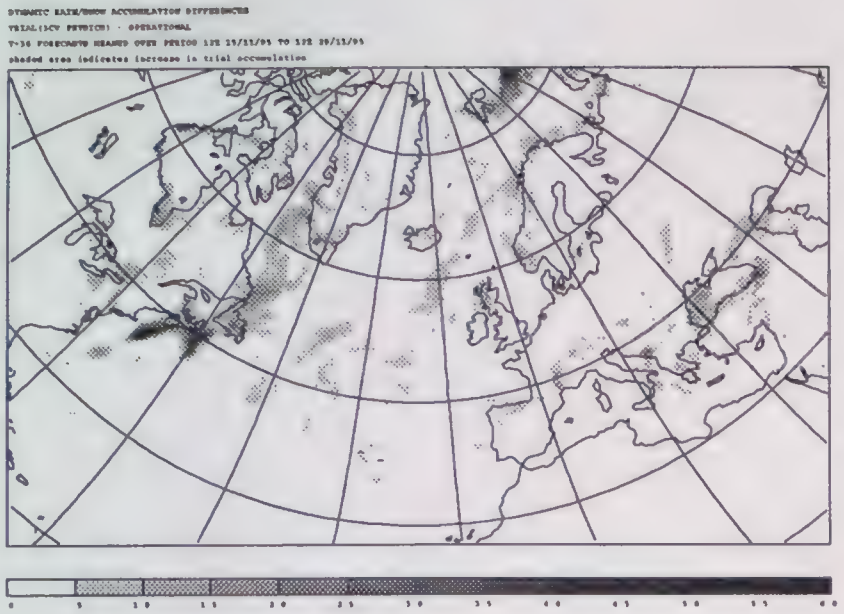
a

b

c

d

FIGURE 4.7



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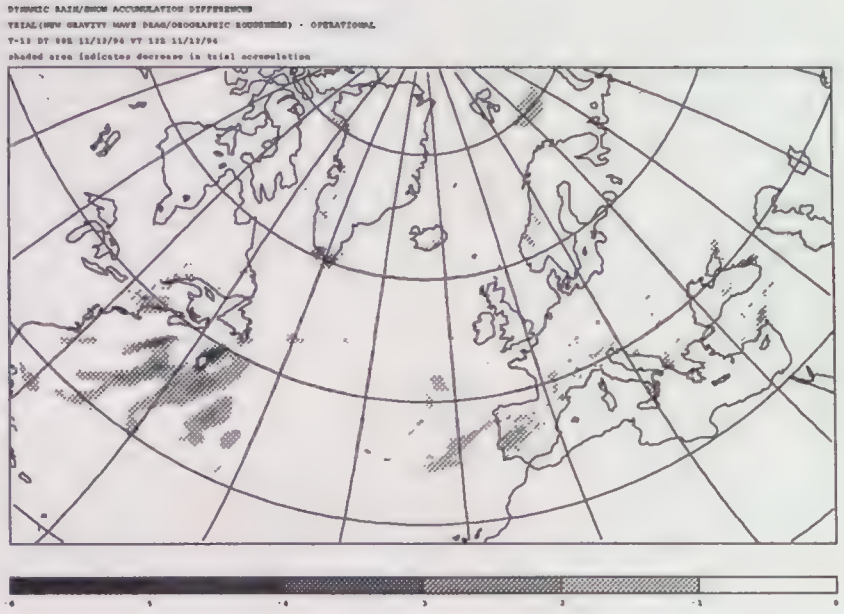
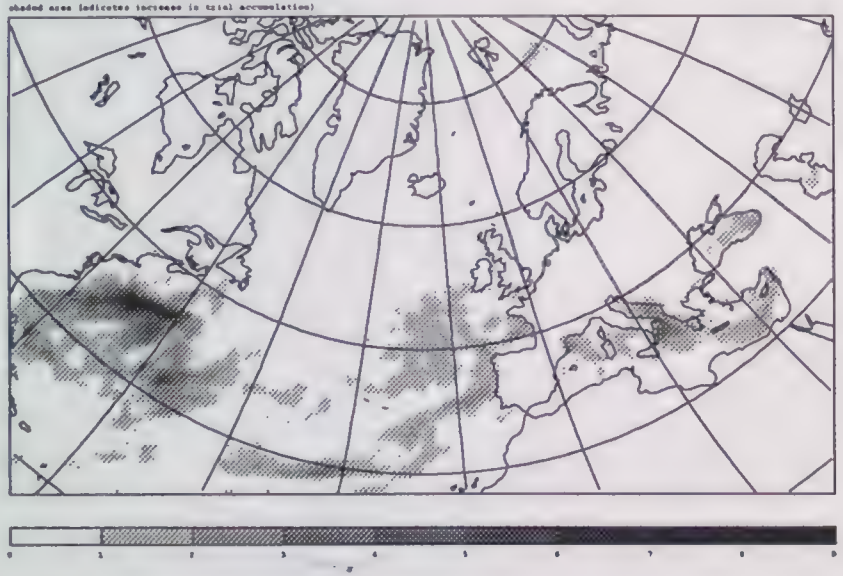
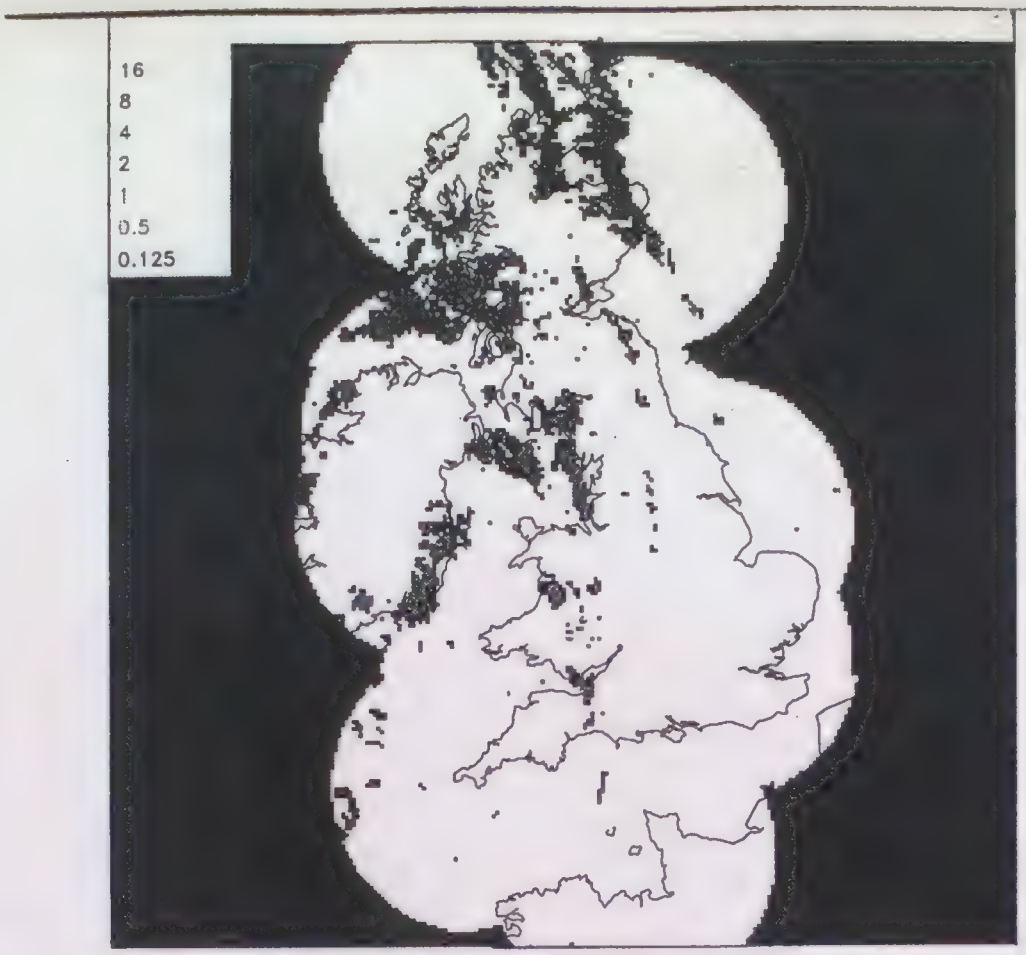


b



c

FIGURE 4.8



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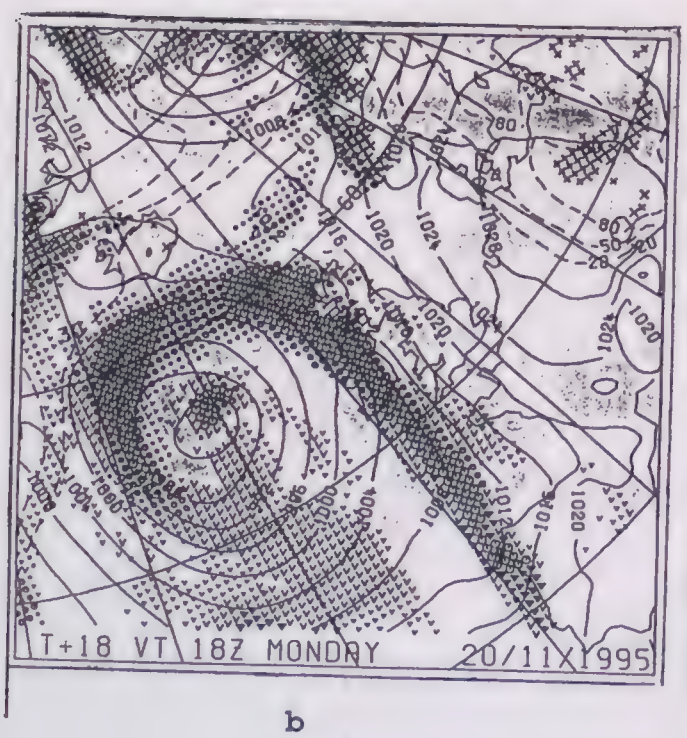
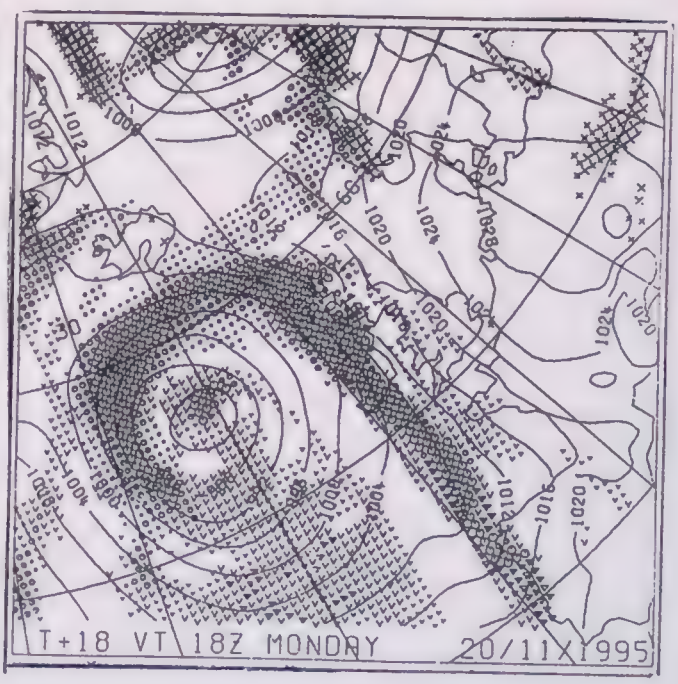


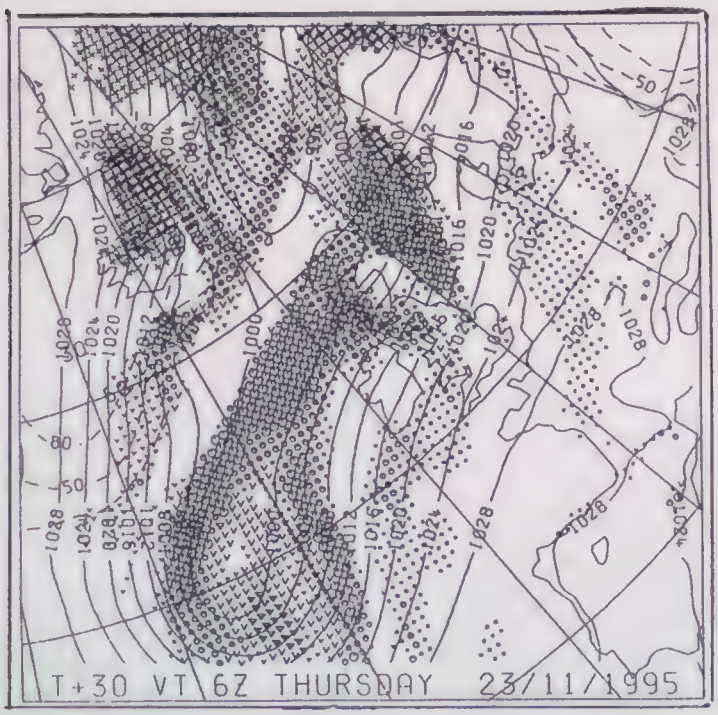
b



c

FIGURE 4.9

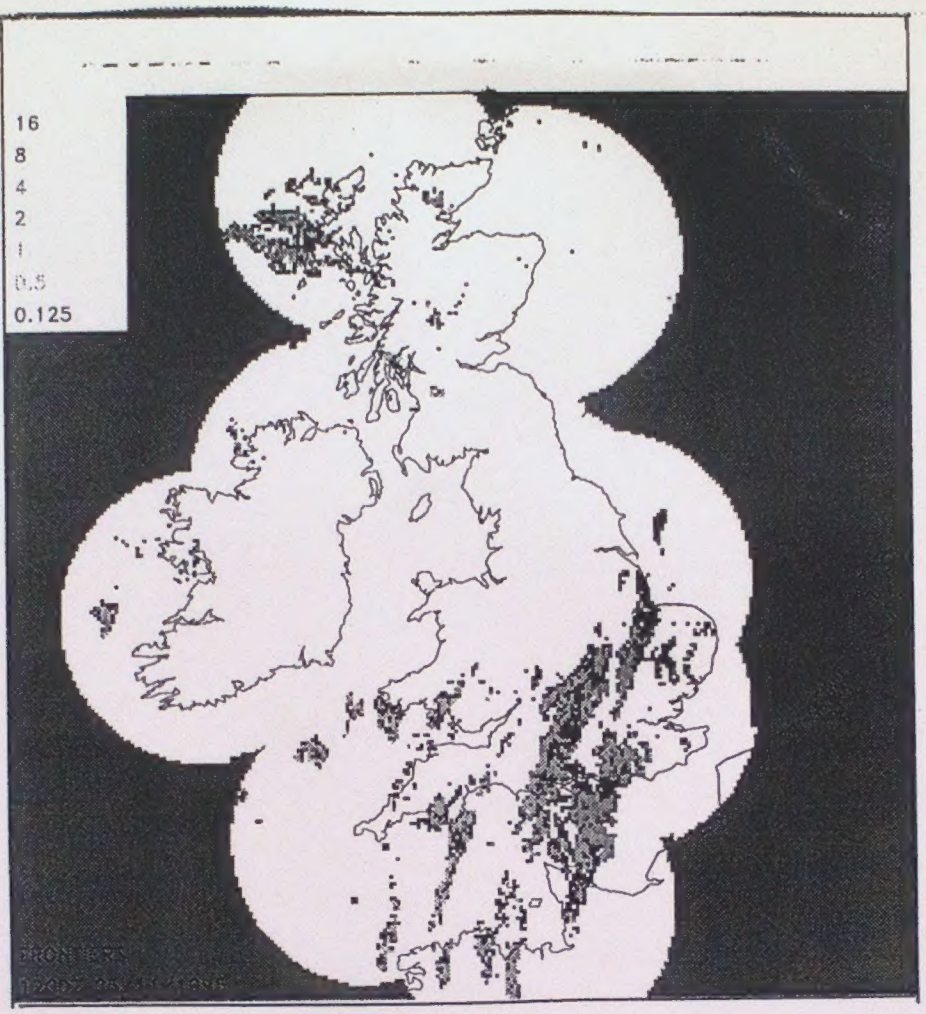
a



b

c

FIGURE 4.10



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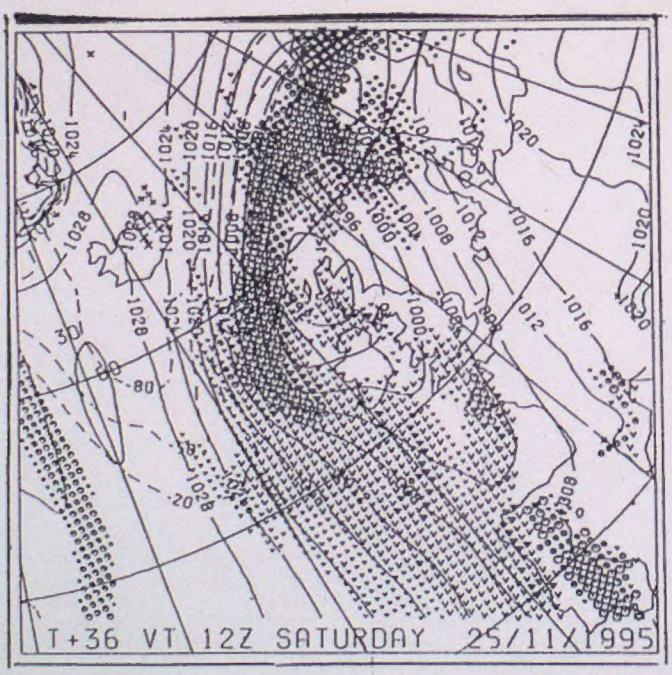
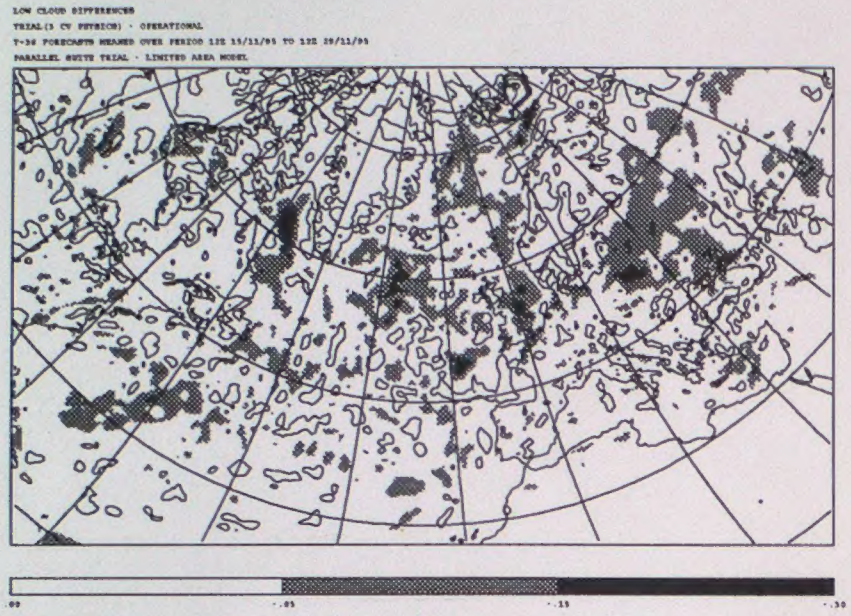


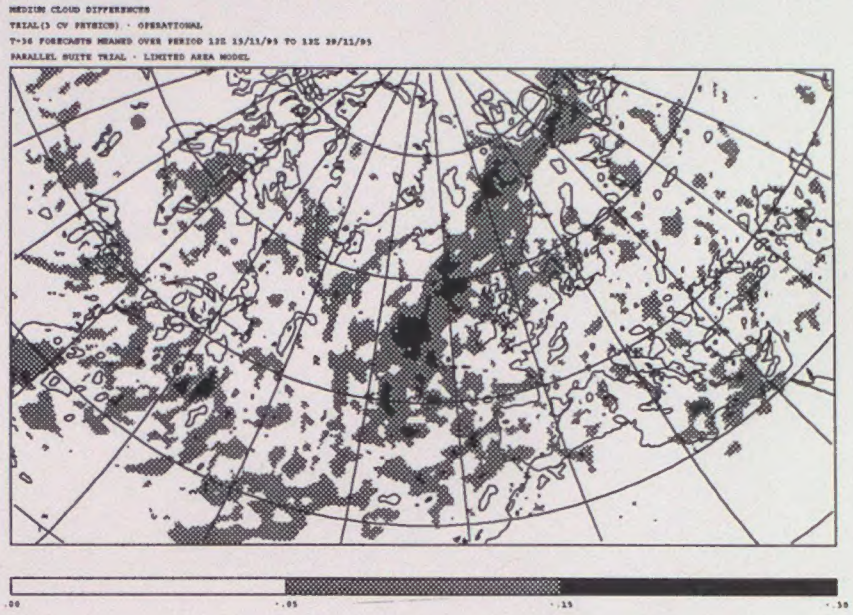
b

c

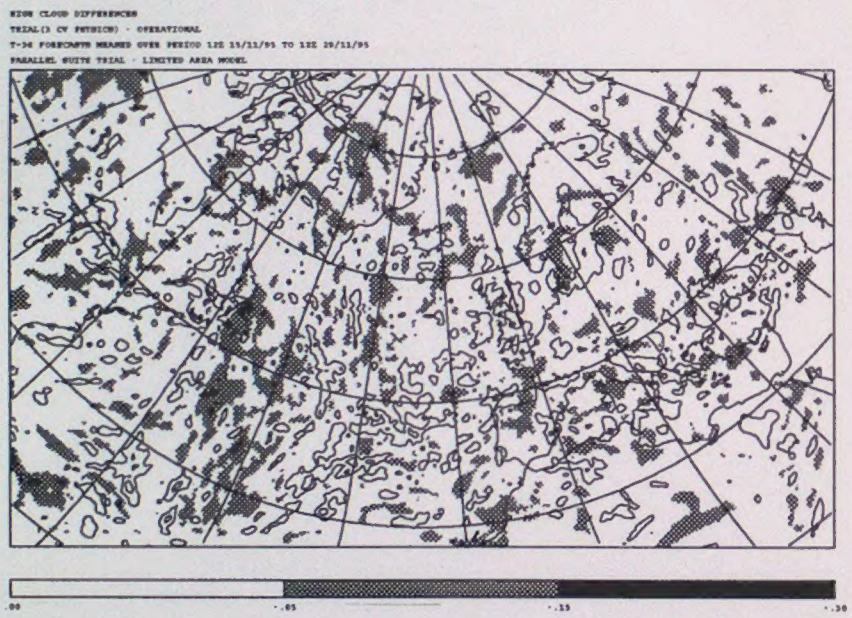
FIGURE 4.11



a



b



c

FIGURE 4.12

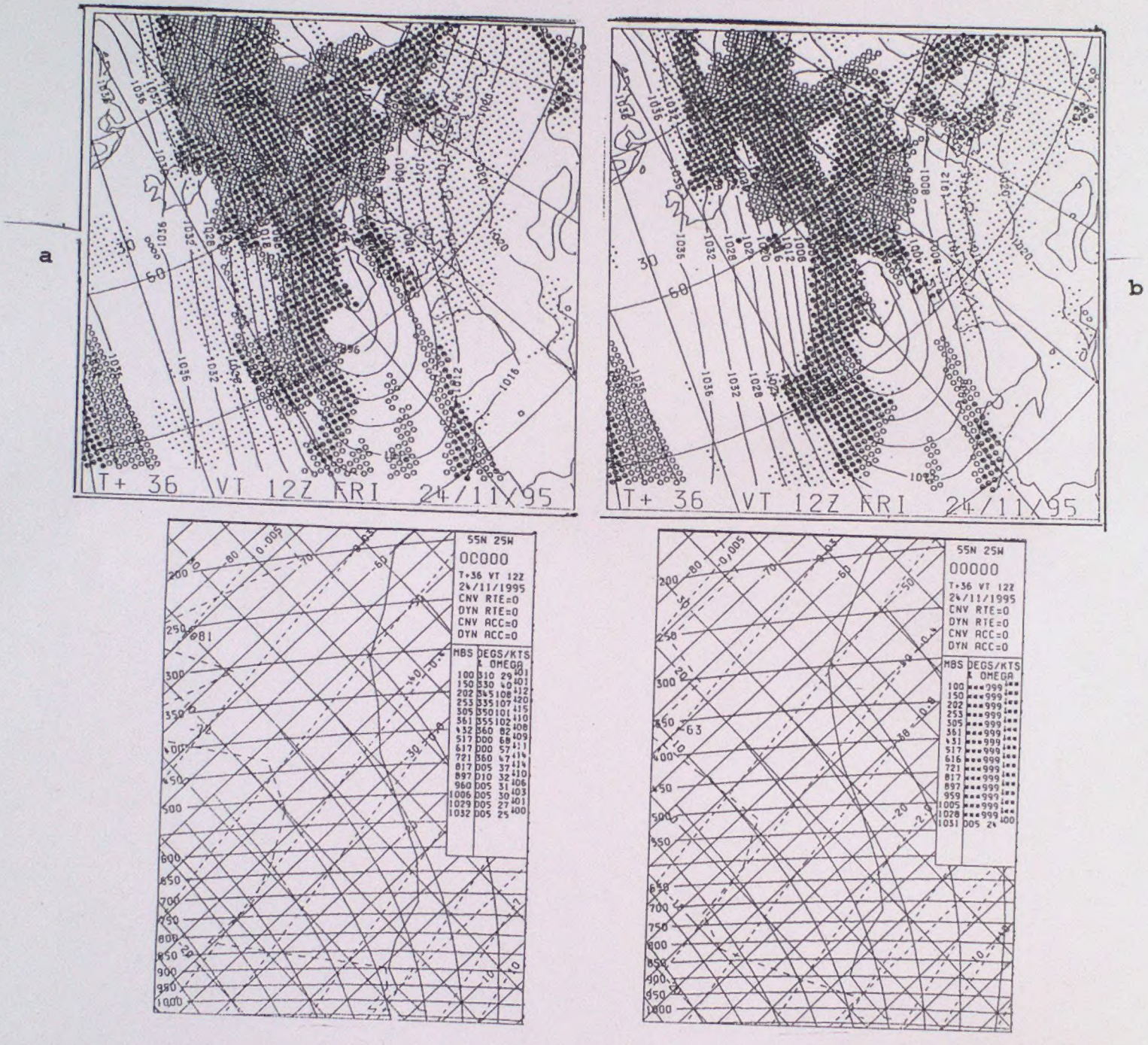
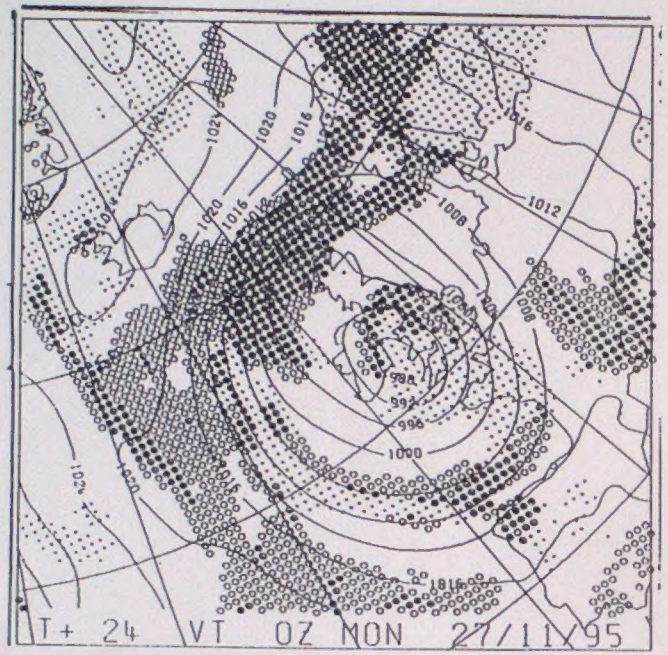
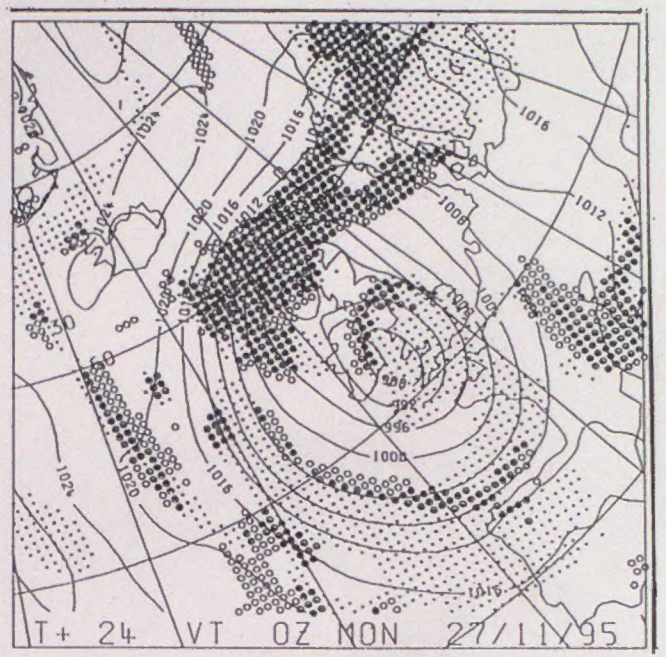

a
b
T+ 36 VT 12Z FRI 24/11X95
T+ 36 VT 12Z FRI 24/11X95
c
d
SSN 25W
00000
T+36 VT 12Z
24/11/1995
CNV RTE=0
DYN RTE=0
CNV ACC=0
DYN ACC=0
MBS DEGS/KTS
& OMEGA
SSN 25W
00000
T+36 VT 12Z
24/11/1995
CNV RTE=0
DYN RTE=0
CNV ACC=0
DYN ACC=0
MBS DEGS/KTS
& OMEGA

FIGURE 4.13



a



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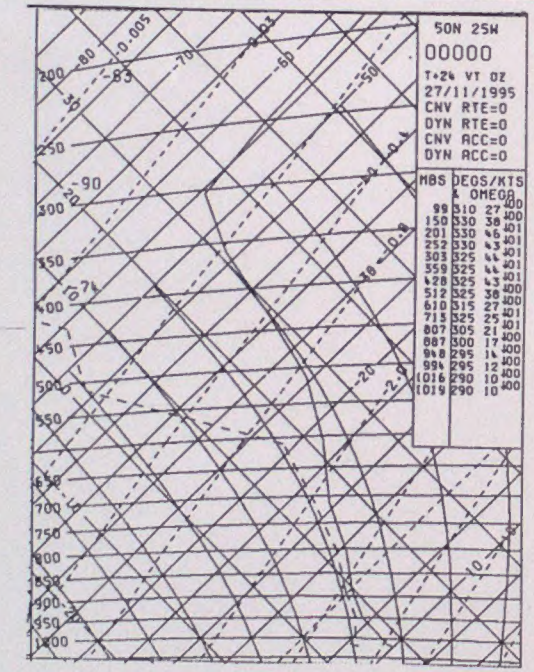

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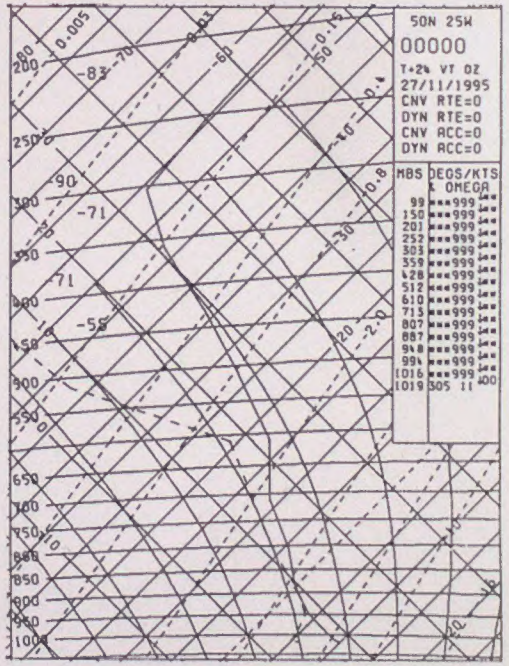

d

FIGURE 4.14